

The Elevation and Duration of Wave Crests

by
William N. Seelig, John P. Ahrens,
and
William G. Grosskopf



MISCELLANEOUS REPORT NO. 83-1

JANUARY 1983



Approved for public release;
distribution unlimited.

U.S. ARMY, CORPS OF ENGINEERS
COASTAL ENGINEERING
RESEARCH CENTER

Kingman Building
Fort Belvoir, Va. 22060

TC
203
0581
MR 83-1

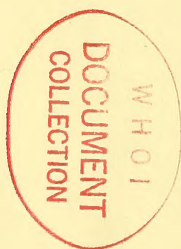
Reprint or republication of any of this material shall give appropriate credit to the U.S. Army Coastal Engineering Research Center.

Limited free distribution within the United States of single copies of this publication has been made by this Center. Additional copies are available from:

*National Technical Information Service
ATTN: Operations Division
5285 Port Royal Road
Springfield, Virginia 22161*

Contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products.

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.



UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER MR 83-1	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) THE ELEVATION AND DURATION OF WAVE CRESTS		5. TYPE OF REPORT & PERIOD COVERED Miscellaneous Report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) William N. Seelig John P. Ahrens William G. Grosskopf		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Department of the Army Coastal Engineering Research Center (CERRE-CS) Kingman Building, Fort Belvoir, VA 22060		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS A31592
11. CONTROLLING OFFICE NAME AND ADDRESS Department of the Army Coastal Engineering Research Center Kingman Building, Fort Belvoir, VA 22060		12. REPORT DATE January 1983
		13. NUMBER OF PAGES 73
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Irregular waves Wave breaking Monochromatic waves Wave crests		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The stream-function wave theory of Dean (1974) is used together with monochromatic and irregular laboratory wave data to develop methods for estimating the elevation and duration of wave crests. The resulting prediction techniques are applied to a wide range of wave conditions measured at CERC's Field Research Facility in Duck, North Carolina, and are shown to give reliable and often conservative estimates of crest elevation. The techniques presented in this report can be used for both nonbreaking and breaking wave conditions.		

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

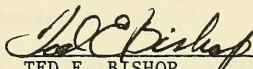
PREFACE

As waves move toward the shoreline they become increasingly nonlinear with the elevation of the wave crests becoming relatively large and short in duration. This report is published to provide coastal engineers with techniques for estimating crest elevation and duration. The techniques were developed using laboratory data from a number of sources covering a wide range of conditions for both monochromatic and irregular waves under nonbreaking and breaking conditions. Predictions compare favorably with wave observations made at the U.S. Army Coastal Engineering Research Center's (CERC) Field Research Facility at Duck, North Carolina. The work was carried out under CERC's Wave Estimation for Design work unit, Coastal Flooding and Storm Protection Program, Coastal Engineering Area of Civil Works Research and Development.

This report was prepared by William N. Seelig, Research Hydraulic Engineer, John P. Ahrens, Oceanographer, and William G. Grosskopf, Hydraulic Engineer, under the general supervision of Dr. R.M. Sorenson, Chief, Coastal Processes and Structures Branch and Mr. R.P. Savage, Chief, Research Division.

Technical Director of CERC was Dr. Robert W. Whalin, P.E.

Approved for publication in accordance with Public Law 166, 79th Congress, approved 31 July 1945, as supplemented by Public Law 172, 88th Congress, approved 7 November 1963.


TED E. BISHOP
Colonel, Corps of Engineers
Commander and Director

CONTENTS

	Page
CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC	7
SYMBOLS AND DEFINITIONS.	8
I INTRODUCTION	9
II LITERATURE REVIEW	9
III SOURCES OF DATA.	11
1. Laboratory Tests Conducted by Authors	11
2. Other Laboratory Tests Used	17
3. Prototype Data Used	17
IV TEST RESULTS AND PREDICTION TECHNIQUES FOR MONOCHROMATIC WAVES .	17
1. Monochromatic Wave Crest Elevations	18
2. Crest Elevation Prediction Aids	18
3. Relative Crest Duration for Monochromatic Waves	24
V TEST RESULTS AND PREDICTION TECHNIQUES FOR IRREGULAR WAVES . . .	24
1. Irregular Wave Crest Elevations	30
2. Crest Elevation Prediction Aids	40
3. The Duration of Irregular Wave Crests	44
VI COMPARISON OF RESULTS FOR PROTOTYPE DATA	44
1. Field Conditions.	44
2. Prototype Verification	44
VII SUMMARY AND CONCLUSIONS.	49
LITERATURE CITED	50
APPENDIX	
A MONOCHROMATIC TESTS RESULTS	51
B IRREGULAR WAVE CREST ELEVATIONS	56
C IRREGULAR WAVE CREST DURATIONS	60
D IRREGULAR WAVE DATA FOR SHOALING CONDITIONS	64
E CNOIDAL WAVE TESTS RESULTS	72
F ESTIMATING THE WAVE CREST ELEVATION AT BREAKING ON A PLANE SLOPE	73

TABLES

1 Summary of CERC laboratory test data	15
2 Values of the empirical coefficients A_2 and A_3 for predicting relative crest.	20

CONTENTS

TABLES--Continued

	Page
3 Observed versus predicted relative crest elevations for monochromatic waves.	20
4 Coefficients for estimating the duration of wave crests	28
5 Observed versus predicted relative crest durations	28
6 Selected irregular wave crest elevation data	31
7 Selected irregular wave crest data for waves breaking on a 1 on 30 slope	33
8 Values of A_1^* for levels of probability of exceedance for irregular waves derived from 122 laboratory experiments	38
9 Values of A_1^* for levels of probability of exceedance for irregular waves on a 1 on 30 laboratory slope.	38
10 Summary of prototype wave conditions.	46
11 Values of crest heights observed and predicted for waves at Duck, North Carolina.	46

FIGURES

1 Example of an extremely nonlinear wave condition	10
2 Predicted monochromatic wave profile.	11
3 Experimental setup in CERC's 4.5-meter-wide tank	12
4 Sample of water level time histories taken at four gages during an irregular wave test	13
5 Experimental setup in CERC's 0.9-meter-wide tank	14
6 Experimental setup in CERC's 0.4-meter-wide tank	15
7 Observed and predicted wave spectra	16
8 Empirical coefficients A_2 and A_3 for estimating η_c/H	19
9 Effect of beach slope on relative wave crest elevation	21
10 Effect of beach slope on breaker crest elevation.	22
11 Wave crest elevation for constant values of wave steepness	23
12 Wave crest elevation for constant values of H/H_b	25
13 η_c/d for constant values of wave height to depth	26
14 Empirical parameters for estimating wave crest durations	27
15 Values of dimensionless wave crest duration	29
16 Sample of irregular wave time histories	30
17 Variation in wave crest elevation for a 1 on 30 slope	33
18 Sample of water level time histories for irregular waves at selected locations along a 1 on 30 slope	34

CONTENTS

FIGURES--Continued

	Page
19 Sample of irregular wave crest elevation distributions	35
20 Sample of wave crest distributions.	36
21 Values of A_1^* for probability of exceedance for irregular waves . . .	37
22 Observed and predicted crest elevations exceeded by 2 percent of the wave crests	39
23 Wave crest elevation exceeded by 13.5 percent of the wave crests . . .	40
24 Crest elevation at the 2-percent probability level of exceedance for irregular waves	41
25 Crest elevation at the 13.5-percent probability level of exceedance for irregular waves	42
26 Wave crest elevations along a 1 on 30 slope for 2- and 13.5- percent probability of exceedance levels	43
27 Dimensionless wave crest duration for irregular waves	45
28 Observed versus predicted crest elevations ($p = 0.135$)	47
29 Observed versus predicted crest elevations ($p = 0.020$)	48

CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	by	To obtain
inches	25.4	millimeters
	2.54	centimeters
square inches	6.452	square centimeters
cubic inches	16.39	cubic centimeters
feet	30.48	centimeters
	0.3048	meters
square feet	0.0929	square meters
cubic feet	0.0283	cubic meters
yards	0.9144	meters
square yards	0.836	square meters
cubic yards	0.7646	cubic meters
miles	1.6093	kilometers
square miles	259.0	hectares
knots	1.852	kilometers per hour
acres	0.4047	hectares
foot-pounds	1.3558	newton meters
millibars	1.0197×10^{-3}	kilograms per square centimeter
ounces	28.35	grams
pounds	453.6	grams
	0.4536	kilograms
ton, long	1.0160	metric tons
ton, short	0.9072	metric tons
degrees (angle)	0.01745	radians
Fahrenheit degrees	5/9	Celsius degrees or Kelvins ¹

¹To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use formula: $C = (5/9) (F - 32)$.

To obtain Kelvin (K) readings, use formula: $K = (5/9) (F - 32) + 273.15$.

SYMBOLS AND DEFINITIONS

A_1, A_1^*, A_2, A_3	empirical coefficients
C_1, C_2, C_3	empirical coefficients
d	water depth
d_b	water depth at the breaking point
H	wave height
H_b	breaking wave height
H'_0	unrefracted deepwater significant wave height
H_s	significant wave height for irregular waves
L_A	wavelength given by Airy wave theory
L_0	deepwater wavelength given by Airy theory
m	beach slope (tangent of the angle between the slope and the horizontal)
p	probability level of exceedance
T	wave period
T_c	duration of wave crest
T_p	period of peak energy density for irregular waves
T_t	duration of the wave trough
$(T_c/T)_p$	mean dimensionless crest duration for all crests above the probability of exceedance level, p
U_R	Ursell number = HL_A^2/d^3
η	water level
η_b	crest elevation at breaking
η_c	elevation of the wave crest above the mean water level (MWL)
$(\eta_c)_p$	elevation of wave crest associated with a probability of exceedance, p
η_{rms}	root-mean-square (rms) water level
η_t	elevation of wave trough (negative)

THE ELEVATION AND DURATION OF WAVE CRESTS

by

William N. Seelig, John P. Ahrens, and William G. Grosskopf

I. INTRODUCTION

Coastal structures are generally built to withstand extreme waves that occur infrequently. One of the important aspects of these waves is that they may be highly nonlinear if the wave steepness is large or the relative water depth is small. Two of the important engineering characteristics of nonlinear waves are that the crest elevations are more than half of the wave height and the duration of the crests are less than half of the wave period.

Crest elevation is important because the forces on a structure may be more strongly related to crest elevation above the water level than the trough distance below the water level. Uplift forces on piers and fixed structures are particularly sensitive to wave crest elevation, which is one of the reasons why most offshore platforms and piers are built well above the water level. Crest elevation also influences wave runoff and overtopping (Weggel, 1976a).

The relatively short duration of nonlinear wave crests is important, because the combination of high elevation and short duration produces large water particle motions and accelerations. These hydraulic characteristics have the potential for suspending sediment, lifting armor units, and causing surprisingly high drag forces on coastal structures.

Figure 1 is a sample wave record made as part of the Coastal Engineering Research Center's (CERC) coastal wave collection program (Thompson, 1977). This example clearly shows the high crest elevations and short crest durations that may occur in coastal waters.

This study develops methods of predicting crest elevations and duration for monochromatic and irregular waves. Laboratory waves are used to minimize the influence of refraction, diffraction, irregular topography, directional spread of wave energy, and multiple wave trains on the characteristics of wave crests. Assumed independent variables used in the prediction methods are water depth, wave period or period of peak energy density for irregular waves, wave height (significant wave height for irregular waves), and beach slope. Predictions are compared to selected prototype wave measurements taken at the CERC Field Research Facility (FRF) at Duck, North Carolina.

II. LITERATURE REVIEW

Goda (1964) performed some basic research on the elevation of monochromatic laboratory wave crests. Using his own data and the data of Bretschneider (1958), Goda found that the ratio of wave height to water depth played a dominant role in determining the relative crest elevation. However, there are considerable scatter in the results.

Jahns and Wheeler (1973) and others have performed theoretical derivations of expected crest heights for irregular wave conditions. Without including nonlinear effects they conclude that a Rayleigh-type distribution should

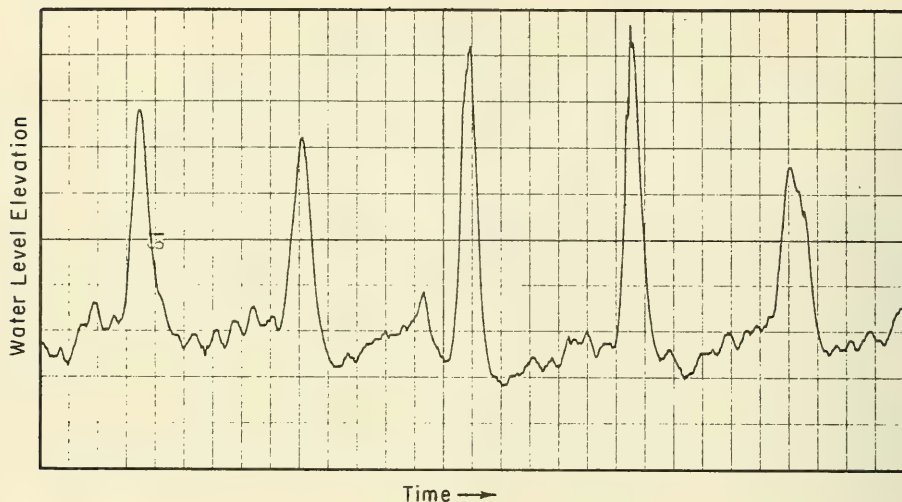


Figure 1. Example of an extremely nonlinear wave condition (recorded by a CERC continuous-wire staff at Lake Worth, Florida, 28 March 1971 at 0820).

provide an upper limit or conservative estimate of crest elevations corresponding to various probabilities of exceedance. Actual irregular wave data have crests that are higher than given by this theory, so Jahns and Wheeler (1973) suggest an empirical correction factor. One limitation of the correction factor is that the observed probability of exceedance may deviate several or many orders of magnitude from the Rayleigh distribution.

Dean (1974) developed one of the most comprehensive theories to date for predicting properties of monochromatic waves traveling over a flat bottom. This higher order stream-function theory can be used to predict crest elevation and duration for a wide range of wave and water level conditions. The theory indicates that in the Airy limit, where the wave amplitude approaches zero, the wave crest elevation is approximately equal to one-half the wave height and the duration of the crest is half the wave period. In the cnoidal wave limit the crest elevation approaches the wave height and the duration of the crest becomes small compared to the wave period. Figure 2 is an example predicted water level time history for a highly nonlinear wave. In this extreme condition the ratio of crest elevation, η_c , to wave height, H , is $\eta_c/H = 0.90$. The duration of the crest, T_c , is one-fourth the wave period, T , or $T_c/T = 0.25$.

Singamsetti and Wind (1980) presented wave crest characteristics for monochromatic laboratory wave conditions at the point of breaking for constant beach slopes, m , of 1 on 40, 1 on 20, 1 on 10, and 1 on 5.

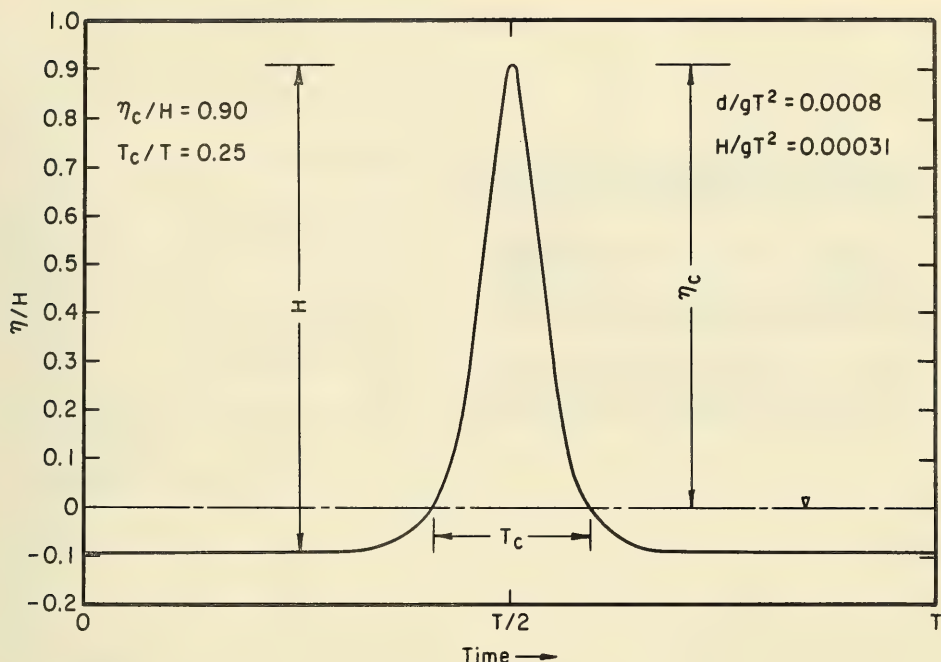


Figure 2. Predicted monochromatic wave profile (after Dean, 1974).

III. SOURCES OF DATA

Sources of data upon which the predictive techniques are based include laboratory data collected by the authors for a wide range of conditions, laboratory data collected by other authors, and field data from the FRF at Duck, North Carolina. Conditions under which these data were collected and methods of analysis are described below.

1. Laboratory Tests Conducted by Authors.

a. Wave Conditions, Data, and Test Setups. Most of the monochromatic wave data and all the irregular wave data collected over a horizontal bottom were obtained in a 105.7-centimeter-wide channel within CERC's 1.2-meter-high by 4.5-meter-wide by 42.6-meter-long wave tank. The monochromatic wave data are tabulated in Appendix A and the irregular wave data are tabulated in Appendixes B and C. A gravel absorber beach with a slope 1 on 12 was used at the end of the channel to reduce wave reflection to a low level. Four paralleled wire resistance-type wave gages were used in the channel to record the wave conditions. A plan view and a profile view of the test setup with gage locations are shown in Figure 3. Figure 4 shows a short section of typical irregular wave records taken approximately simultaneously at each of the four gages. The time axis of the records has been shifted slightly to place the highest crest in the center of each section to show the differences in the time

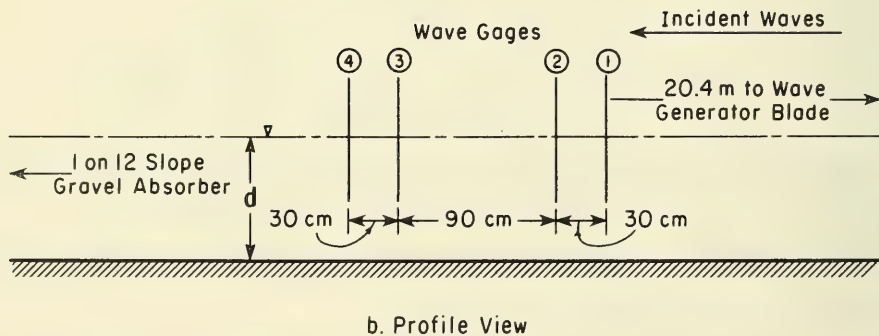
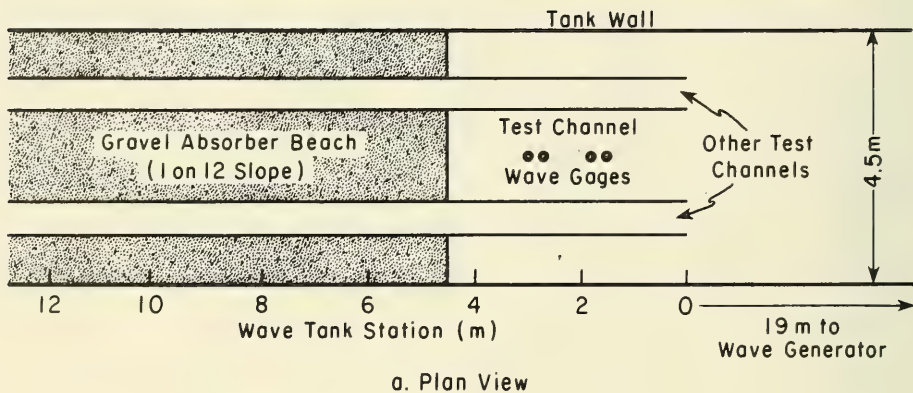


Figure 3. Experimental setup in CERC's 4.5-meter-wide tank.

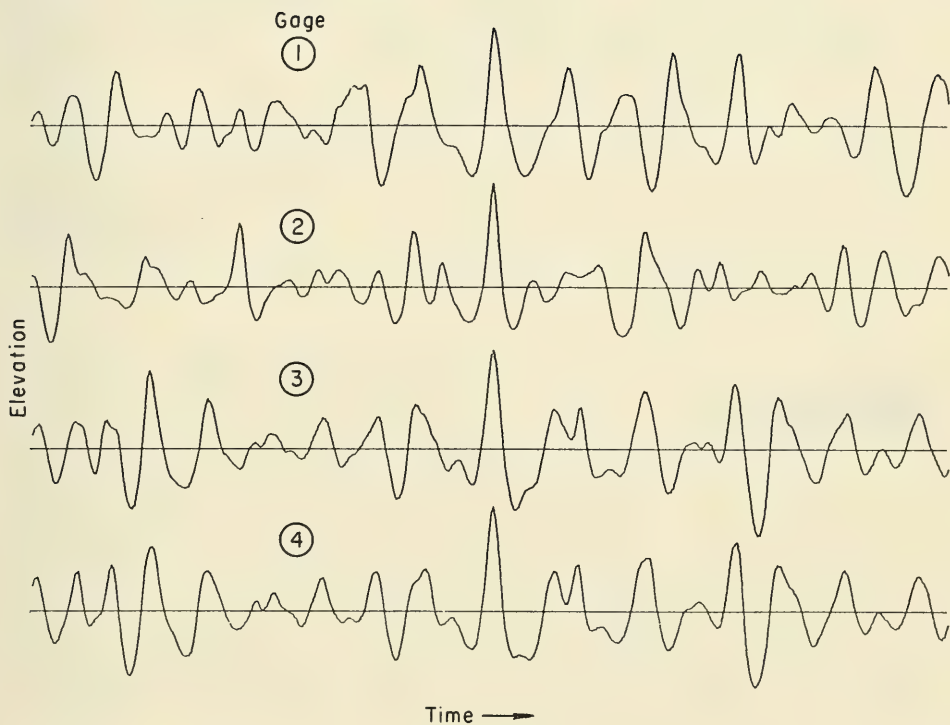


Figure 4. Sample of water level time histories taken at four gages during an irregular wave test (time axis was shifted for the highest crest to appear at the center of each plot).

sequences of the records. Since gages 1 and 4 are the farthest apart they show the greatest differences. The data from gages 1 and 4 are tabulated in Appendixes A, B, and C.

Some additional monochromatic wave data over a horizontal bottom were collected in CERC's 0.9-meter-high by 0.9-meter-wide by 45.7-meter-long wave tank. This tank has a 1 on 30 hogs hair absorber beach to keep reflected wave energy to very low levels. Three parallel wire resistance-type wave gages were used to record the wave conditions. A profile view of the test setup is shown in Figure 5; the data are tabulated in Appendix A.

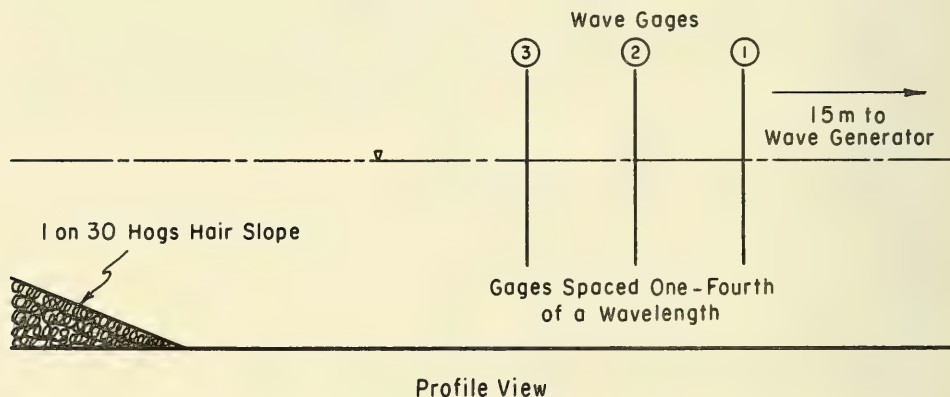


Figure 5. Experimental setup in CERC's 0.9-meter-wide tank.

Wave data were also collected in CERC's 0.9-meter-high by 0.4-meter-wide by 45.7-meter-long wave tank. The setup in this tank was designed to obtain data on the shoaling and breaking of irregular waves. Ten parallel wire wave gages were used: three gages over the horizontal tank bottom and seven over a 1 on 3 concrete slope. Figure 6 shows a profile view of the test setup and gage locations; the data are tabulated in Appendix D.

Table 1 provides a summary of the wave conditions, data and test setups used in the laboratory tests.

b. Procedures and Analysis. All the waves were generated using hydraulically actuated piston-type wave makers. The monochromatic waves studied included waves with sinusoidal blade motion with Ursell numbers less than 25 and cnoidal waves with Ursell numbers greater than 25. The Ursell number, U_R , is defined

$$U_R = \frac{HL_A^2}{d^3} \quad (1)$$

where H is the average wave height over the flat bottom part of the wave tank and L_A the local wavelength, calculated using linear theory and defined by

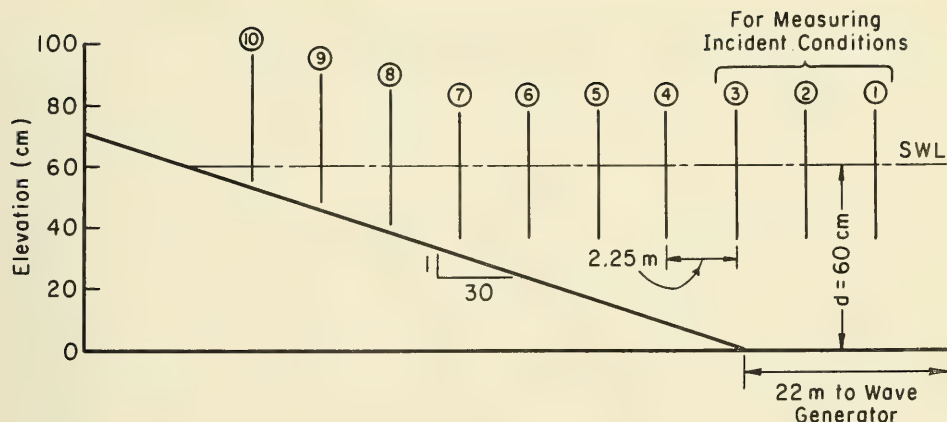


Figure 6. Experimental setup in CERC's 0.4-meter-wide tank

Table 1. Summary of CERC laboratory test data.

Wave tank	Wave conditions	Bottom slope	Test setup, Fig. No.	Data in App.
1.2 by 4.5 by 42.6 m	Monochromatic	Horizontal	3	A
1.2 by 4.5 by 42.6 m	Irregular	Horizontal	3	B, C
0.9 by 0.9 by 45.7 m	Monochromatic	Horizontal	5	A
0.9 by 0.4 by 45.7 m	Irregular	Horizontal and 1 on 30	6	D

$$L_A = \frac{gT^2}{2\pi} \tanh\left(\frac{2\pi d}{L_A}\right) \quad (2)$$

where T is the wave period and d the water depth. For sinusoidal blade motion the restriction on the Ursell number was to eliminate the influence of secondary waves; the cnoidal wave data were collected by Weggel (1976b) and are discussed in Section 2.

The irregular waves used in this study included a wide range of spectral types and relative depths. Spectra were simulated by taking various theoretical spectra, such as Pierson-Moskowitz, Joint North Sea Wave Project (JONSWAP), Bretschneider, and the six-parameter spectra of Ochi and Hubble (1976), and slicing the spectra into 60 equal area segments with each segment represented by a sinusoidal component at the frequency of the midpoint of the segment. Each component was transformed into a piston blade motion using Biesel's equation (Biesel, 1951) at the given frequency and assuming a random-phase relation among the components. The time histories of the 60 components were

linearly superimposed to determine the generator blade motion. Figure 7 shows a sample of observed and predicted wave spectra.

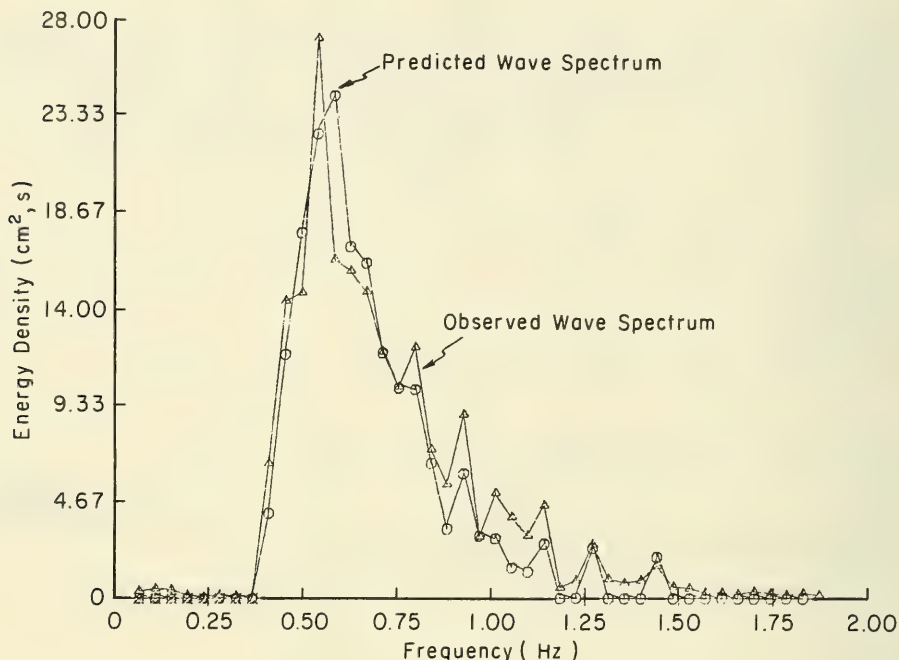


Figure 7. Observed and predicted wave spectra (sample of Pierson-Moskowitz spectra).

In all tests the water surface time history was recorded at each wave gage for 4,096 data points. A sampling rate of 16 times per second was used for waves with periods less than 3 seconds, and a rate of 8 times per second was used for waves with periods greater than 3 seconds. The data were digitized and recorded on magnetic tape through the use of a Data Acquisition System (DAS). An analysis of the tapes was performed later on a general-purpose computer.

Two distinct types of data analysis were performed on the digitized wave records: a fast Fourier transform (FFT) and a zero up-crossing analysis. The FFT was used to determine the spectrum of the wave record, such as shown in Figure 7, which in turn was used to determine the period of peak energy density. The period of peak energy density, T_p , is the reciprocal of the frequency of the midpoint of the 11 consecutive spectral lines with the most wave energy. The zero up-crossing method of analysis is used to determine the wave heights, crest heights, wave periods, and crest durations of individual waves in irregular wave trains or average values for monochromatic wave trains. Crest height, η_c , is measured relative to the mean water level (MWL) and

crest duration, T_c , is the time difference between an adjacent zero up-cross and a zero down-cross; zero indicates the MWL of the record. The significant wave height, H_s , for irregular waves was computed by multiplying the root-mean-square (rms) water surface displacement by four. All the analysis was based on the assumption that there was no wave reflection in any of the channels where data were collected.

For irregular wave conditions the elevations of the wave crests were ranked from the highest to the lowest and the probability of exceedance, p , for various levels of probability were calculated. For example, $\eta_{0.01}$ indicates a crest height with a probability of being exceeded by 1 percent of the crest heights, i.e., $p = 0.01$. Since the larger waves were of the most interest the following probability levels for crest heights were calculated: $p = 0.005, 0.01, 0.02, 0.05, 0.10, 0.135, 0.15$. Dimensionless wave crest height probability levels, $(\eta_c)_p/H_s$, for wave gages 1 and 4 of the test setup shown in Figure 3 are tabulated in Appendix B. The mean dimensionless crest duration, $(T_c/T)_p$, was also determined for the highest 5, 10, 15, 20, 25, 33, and 100 percent of the wave crests for gages 1 and 4 and is tabulated in Appendix C.

2. Other Laboratory Tests Used.

Weggel (1976b) conducted tests using nonsinusoidal blade motion to generate cnoidal waves. These waves have Ursell numbers between 27 and 184 and are relatively free of secondary waves. The cnoidal wave conditions are given in Appendix E.

Singamsetti and Wind (1980) studied the breaking of monochromatic waves on a number of smooth laboratory slopes. The relative crest elevations at breaking η_b/H_b and the relative crest durations at breaking, $(T_c/T)_b$ are tabulated in Appendix A, where η_b is the height of the crest above MWL at breaking, H_b is the wave height at breaking, and T is the period of a monochromatic wave.

3. Prototype Data Used.

Prototype wave data collected at FRF, Duck, North Carolina, are used in this study, particularly the data measured during a major storm in October 1980 in which a large variety of wave steepnesses were observed. The gages were Waverider buoys located 0.5, 3, 6, and 12 kilometers from shore in an area where the bottom contours were generally straight and parallel. The dominant wave direction was approximately along the line of the instruments. The data were analyzed in the same manner as that previously described for the laboratory data.

IV. TEST RESULTS AND PREDICTION TECHNIQUES FOR MONOCHROMATIC WAVES

Monochromatic laboratory wave test results are compared with Dean's stream-function wave theory (1974) and the resulting prediction techniques are discussed.

1. Monochromatic Wave Crest Elevations.

a. Waves Traveling Over a Horizontal Bottom. Dean (1974) developed a stream-function wave theory to predict a number of wave characteristics for waves propagating over a flat horizontal bottom for a number of relative depths and wave heights equal to 0.25, 0.50, 0.75, and 1.00 of the breaking limit. An examination of the tabular values of η_c/H (Dean, 1974, Vol. II) shows that relative crest height can be approximated using the empirical relation:

$$\frac{\eta_c}{H} = \frac{A_1}{1.0 + \tanh \left[-A_2 \ln \left(A_3 \frac{H}{L_0} \right) \right]} \quad (3)$$

where L_0 is the deepwater wavelength given by Airy theory as

$$L_0 = \frac{gT^2}{2\pi} \quad (4)$$

Wave trough elevation, η_t , is equal to wave height minus crest elevation. Dean's tabular results are compared with equation (3) and A_1 is found to be 1.0 for wave traveling over a flat bottom ($m = 0.0$). Values of A_2 and A_3 are functions of relative depth (d/L_0 or $d/(gT^2)$), as shown in Figure 8 and given in Table 2.

Laboratory data in this study show excellent agreement with Dean's stream-function theory and give a value $A_1 = 0.992 \pm 0.0393$ (Table 3). Cnoidal waves ($U_b > 25$) have slightly smaller values of this empirical parameter with $A_1 = 0.95 \pm 0.038$ (Table 3).

b. Waves on a Slope. Singamsetti and Wind's (1980) data are used to evaluate A_1 for monochromatic waves at the breaking point on various beach slopes. Wave crest elevations, as indicated by A_1 , decrease approximately linearly with beach slope, m (Table 3, Fig. 9). For example, waves at the breaking point on a 1 on 5 slope ($m = 0.20$) have only 67 percent of the crest elevations of a wave with same $H/(gT^2)$ and $d/(gT^2)$ traveling over a flat bottom.

Figure 10 illustrates the predicted influence of beach slope on the breaking crest elevation for a sample wave tank condition. In this case waves in the incident flat part of the tank have $d/(gT^2) = 0.019$ and $H/d = 0.37$. The figure shows the predicted crest elevation at the breaking point using the method described in Appendix F for estimating η_c . In this example slopes flatter than 1 on 20 have little influence on the crest elevation, while slopes steeper than 1 on 20 produce lower crest elevations.

2. Crest Elevation Prediction Aids.

Equation (3), which is used for predicting monochromatic wave crest elevations, can be presented in a number of graphical forms useful for predicting and understanding trends in relative crest elevation. Figure 11 shows η_c/H versus relative depth for various wave steepnesses. Relative crest elevation,

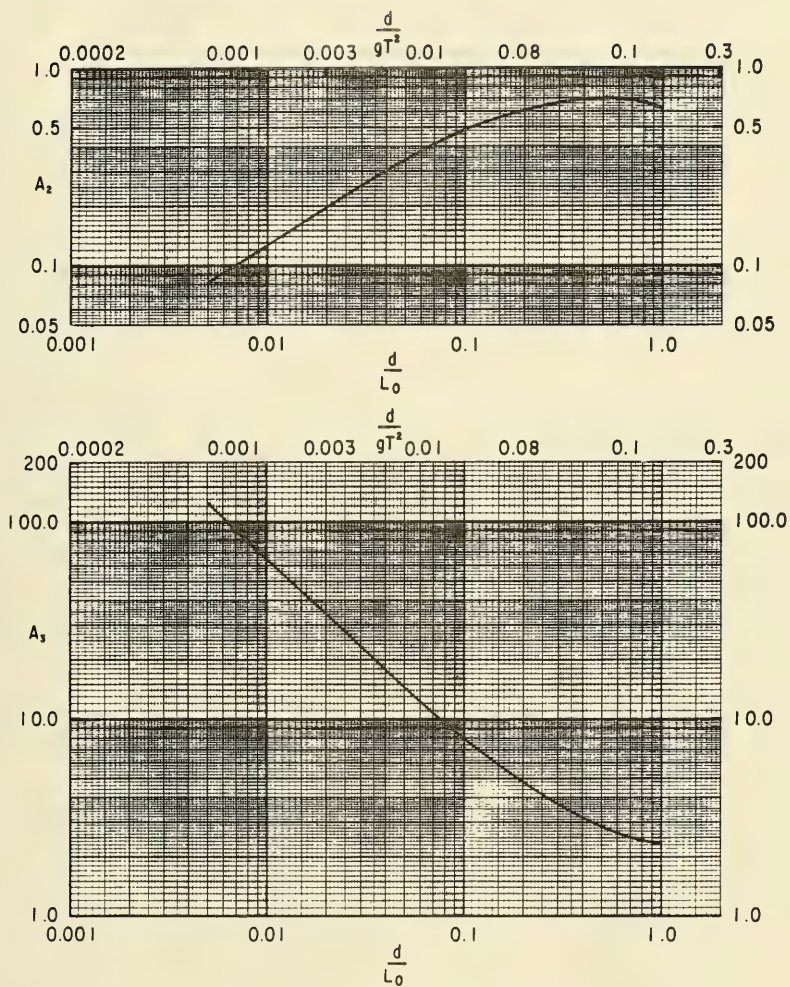


Figure 8. Empirical coefficients A_2 and A_3 for estimating n_c/H .

Table 2. Values of the empirical coefficients A_2 and A_3 for predicting relative crest.¹

d/L_0	d/gT^2	A_2	A_3
0.005	0.000796	0.0791	125.9
0.01	0.00159	0.124	67.6
0.02	0.00318	0.197	35.5
0.05	0.00796	0.353	15.07
0.10	0.0159	0.498	7.71
0.20	0.0318	0.609	4.11
0.50	0.0796	0.698	2.82
1.0	0.159	0.624	2.37

¹Elevation for horizontal bottoms, using equation (3) and $A_1 = 1.0$.

Table 3. Observed versus predicted relative crest elevations for monochromatic waves.

Type of wave generator motion	$1/m$	A_1	Std. dev.	Coefficient of variation (pct)	No. of tests	U_R range	Source
Sine	00	0.992	0.0393	4.0	53	0.3 to 25	This study
Cnoidal	00	0.95	0.038	4.0	13	27 to 184	Weggel (1976b)
Sine	40	0.909 ¹	0.0375	4.1	26	3.7 to 24	Singamsetti and Wind (1980)
Sine	20	0.88 ¹	0.035	4.0	12	1.8 to 24	Singamsetti and Wind (1980)
Sine	10	0.818 ¹	0.0752	9.2	22	2.5 to 23	Singamsetti and Wind (1980)
Sine	5	0.672 ¹	0.0370	5.5	21	2.0 to 22	Singamsetti and Wind (1980)

¹At the breaking point.

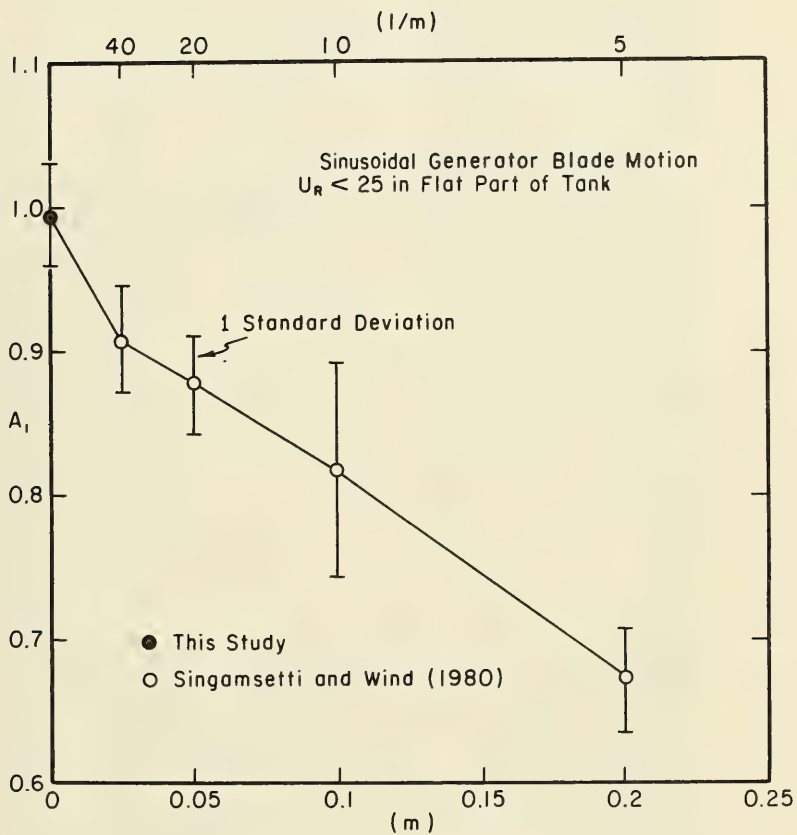


Figure 9. Effect of beach slope on relative wave crest elevation.

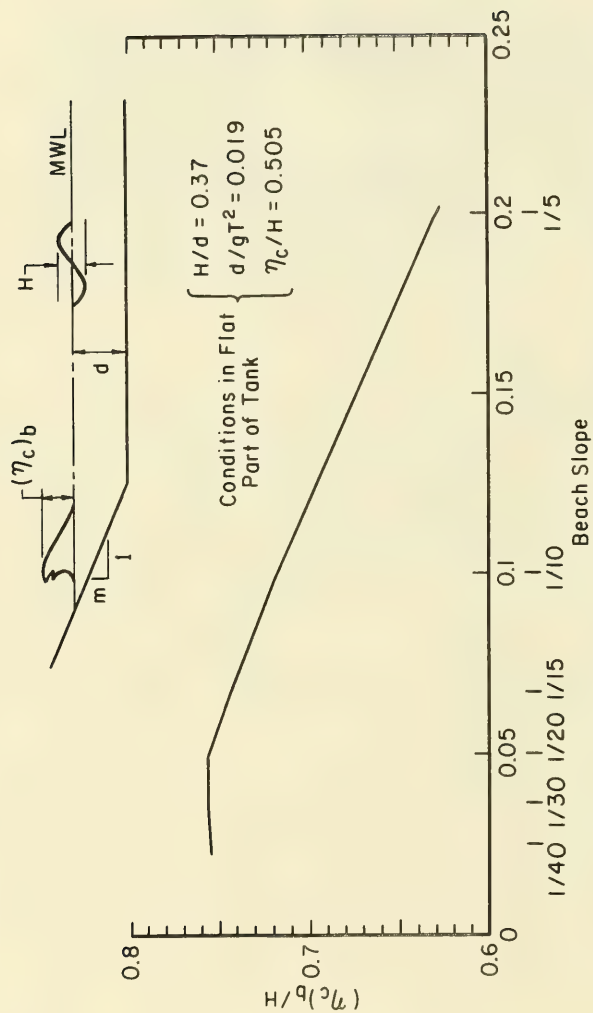


Figure 10. Effect of beach slope on breaker crest elevation.

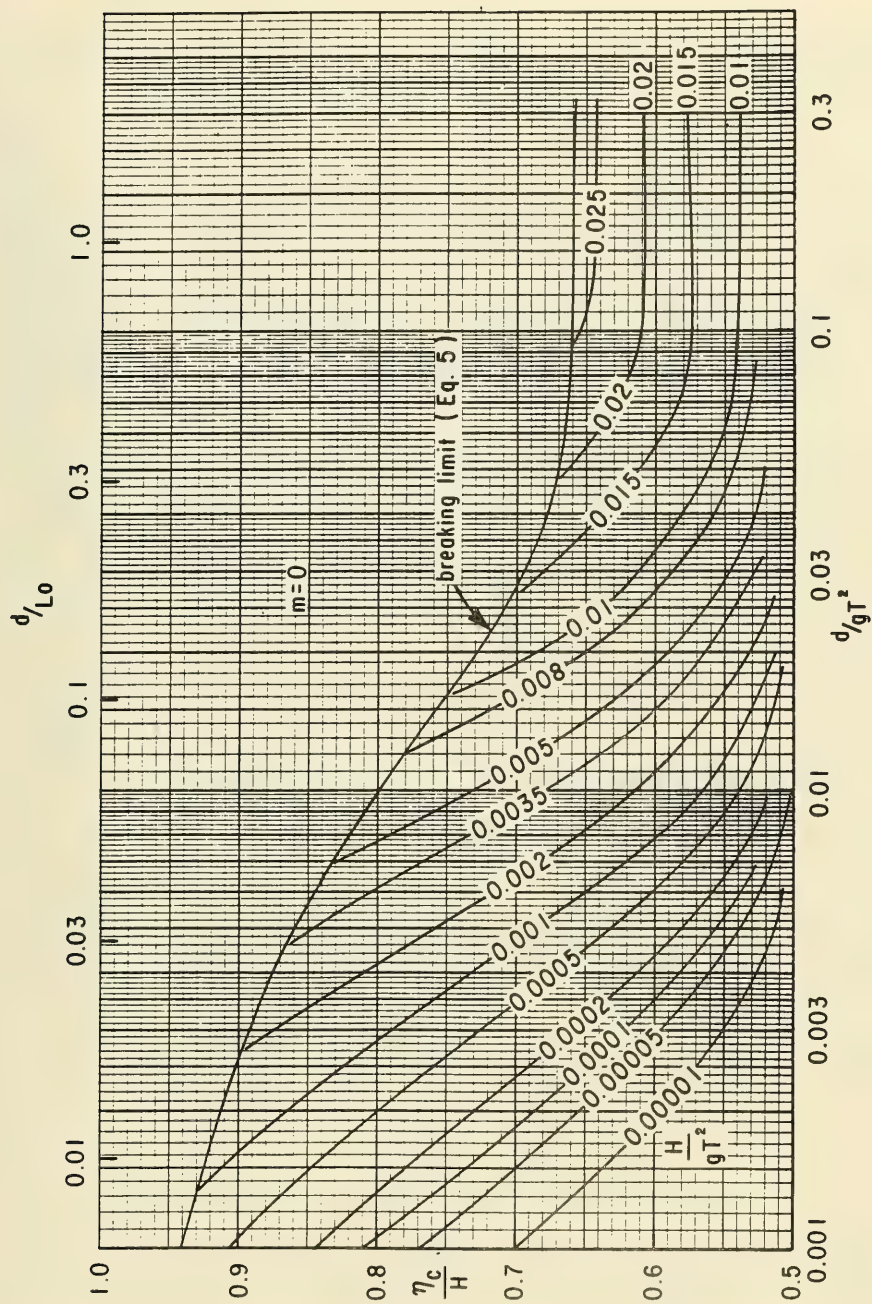


Figure 11. Wave crest elevation for constant values of wave steepness.

η_c/H , is strongly influenced by $d/(gT^2)$ for a given value of wave steepness for $d/(gT^2) > 0.05$. The breaking limit, H_b , given in this figure is from Goda (1975):

$$H_b = 0.17 L_o \left\{ 1.0 - \exp \left(-4.712 \frac{d}{L_o} \left[1.0 + 15m^{1.333} \right] \right) \right\} \quad (5)$$

Figure 12 presents η_c/H for constant values of the ratio of wave height to breaker height, H/H_b . The figure shows that in relatively deep water, η_c/H only deviates from the Airy condition of $\eta_c/H = 0.5$ when the wave height becomes a significant fraction of the breaking wave height. Relatively shallower water causes a wave to become more nonlinear, even when the wave height is small compared to the maximum possible breaker height. For example, $\eta_c/H = 0.75$ at $d/(gT^2) = 0.0015$ for $H/H_b = 0.1$ (Fig. 12).

The parameter η_c/d is presented in Figure 13 for constant values of H/d at various values of $d/(gT^2)$. This figure shows the combined influence of wave steepness and water depth on crest elevation. η_c/d reaches a minimum for constant values of H/d at $d/(gT^2)$ in the neighborhood of 0.03. At values of $d/(gT^2)$ larger than 0.03 the increasing wave steepness causes η_c/d to increase until the breaking point is reached. For smaller values of $d/(gT^2)$ the decreased depth or increased period produces greater wave nonlinearity and increased η_c/d .

3. Relative Crest Duration for Monochromatic Waves.

As waves become increasingly nonlinear the duration of the crest, T_c , decreases to less than half of the wave period. Values of relative crest duration, T_c/T , predicted by stream-function theory (Dean, 1974) can be approximated by the empirical relation:

$$\frac{T_c}{T} = C_1 \tanh \left[C_2 \ln \left(C_3 \frac{L_o}{H} \right) \right] \quad (6)$$

where C_1 , C_2 , and C_3 are empirical coefficients with $C_1 = 0.5$ for waves on a flat bottom ($m = 0.0$). Values of C_2 and C_3 are given in Figure 14 and Table 4. Good correlation is found between equation (6) and experimental data for small beach slopes as shown in Table 5. However, the equation does not apply to beach slopes steeper than 1 on 20 ($m = 0.05$).

Figure 15 presents predicted values of T_c/T as functions of $d/(gT^2)$ and $H/(gT^2)$. Note that the duration of the wave trough, T_t is given by

$$\frac{T_t}{T} = 1.0 - \frac{T_c}{T} \quad (7)$$

V. TEST RESULTS AND PREDICTION TECHNIQUES FOR IRREGULAR WAVES

Irregular wave crest elevations and durations are more variable than monochromatic wave conditions because wave energy is distributed over a range of frequencies. This energy distribution produces waves with a variety of heights and periods, which have varying amounts of nonlinearity. Larger waves are of

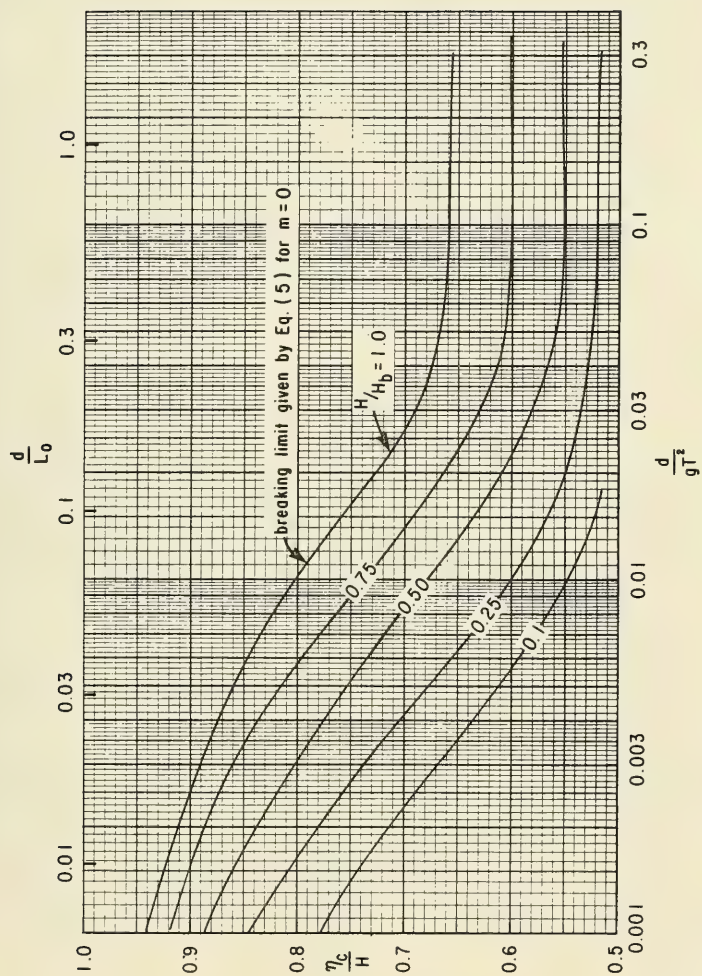


Figure 12. Wave crest elevation for constant values of H/H_b .

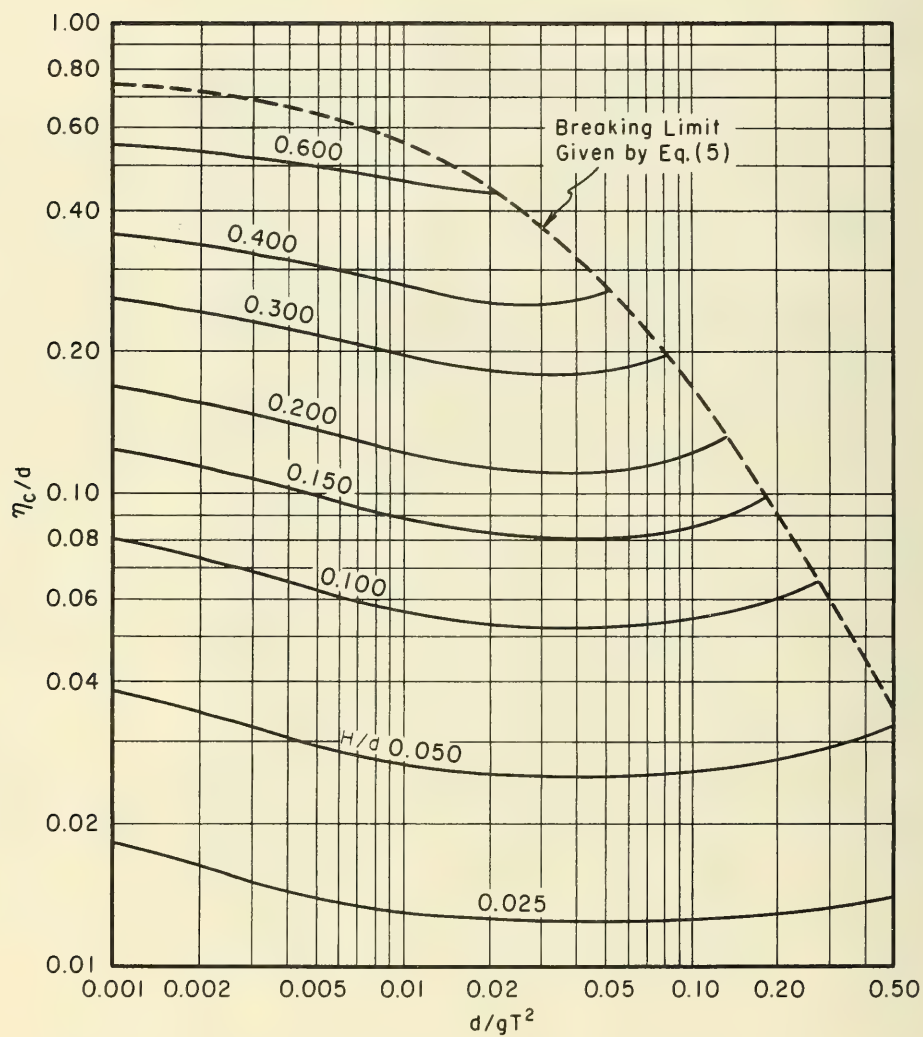


Figure 13. η_c/d for constant values of wave height to depth.

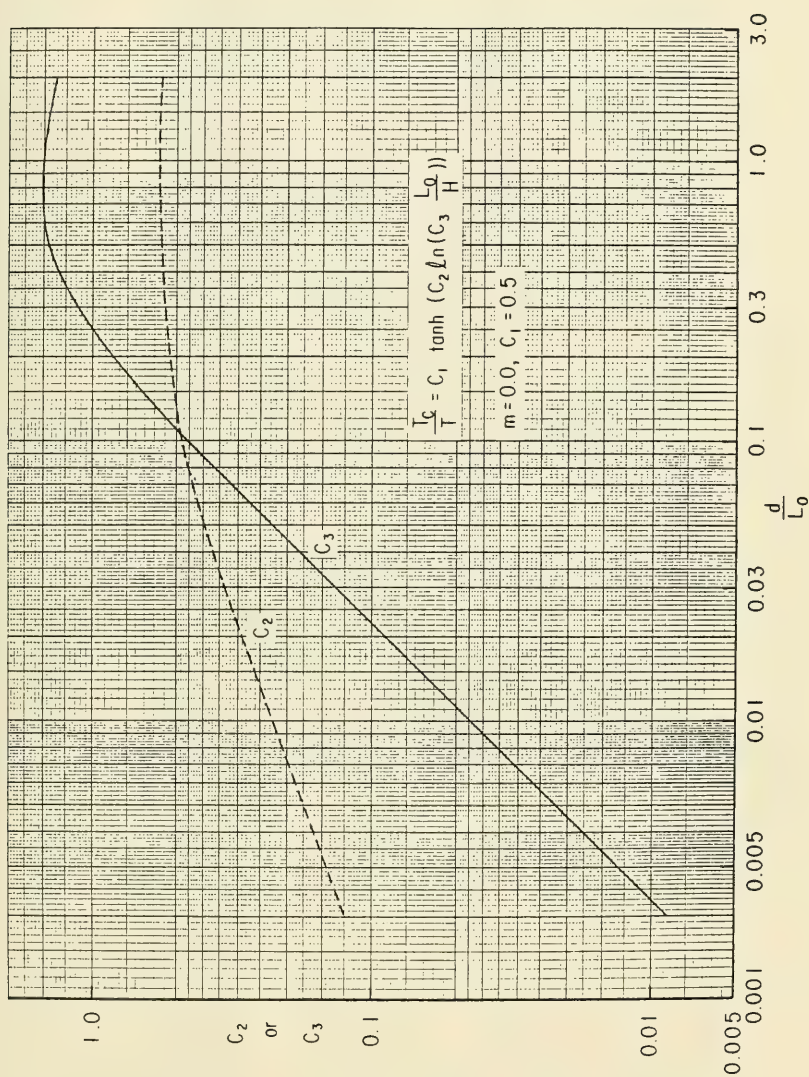


Figure 14. Empirical parameters for estimating wave crest durations ($m = 0.0$).

Table 4. Coefficients for estimating the duration of wave crests.¹

d/L_0	d/gT^2	C_2	C_3
0.002	0.00032	0.1242	0.00788
0.005	0.00080	0.1784	0.0205
0.01	0.0016	0.2025	0.044
0.02	0.0032	0.2903	0.0852
0.05	0.0080	0.4036	0.2058
0.1	0.016	0.4702	0.4529
0.2	0.032	0.5442	0.8268
0.5	0.080	0.5518	1.448
1.0	0.16	0.5542	1.4601
2.0	0.32	0.5691	1.363

¹ $C_1 = 0.5$ for waves on a flat bottom
($m = 0.0$).

Table 5. Observed versus predicted relative crest durations (monochromatic waves-sinusoidal generator blade motion).

$1/m$	Mean value of C_1	Std. dev. of C_1	Coefficient of variation of C_1 (pct)	No. of tests	Source
∞	0.498	0.042	8.4	23	This study
40 ¹	0.53	0.104	19.6	26	Singamsetti and Wind (1980)
20 ¹	0.56	0.11	19.6	24	Singamsetti and Wind (1980)
10 ¹	0.70	0.42	60.0	22	Singamsetti and Wind (1980)
5 ¹	0.91	0.32	35.2	21	Singamsetti and Wind (1980)

¹At the breaking point.

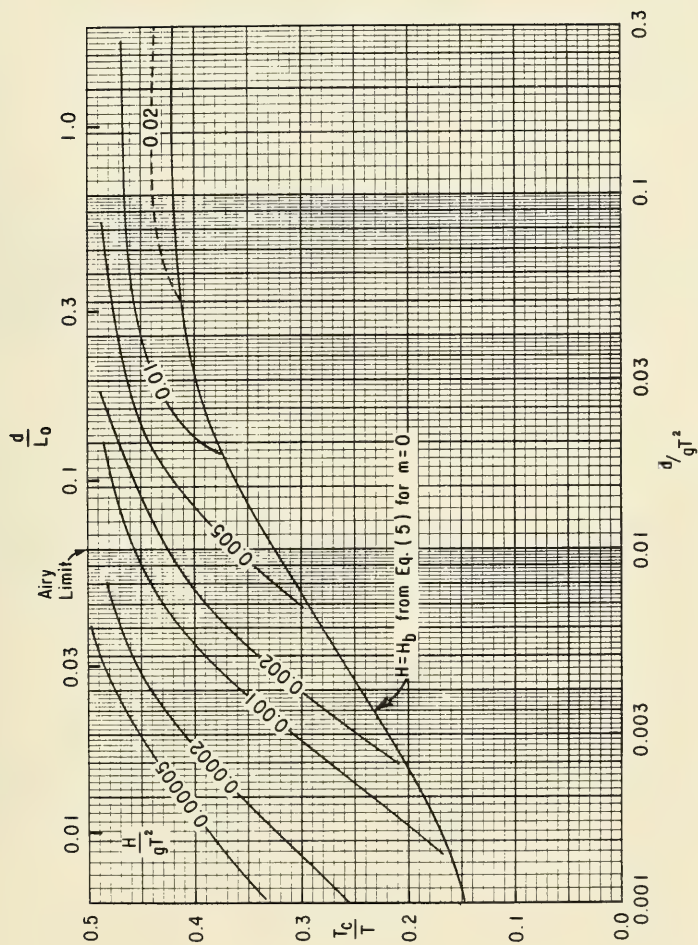


Figure 15. Values of dimensionless wave crest duration.

greatest interest, so the primary emphasis of this analysis is on the highest 15 percent of wave crests in a wave train. The variable p is used to designate the probability level of exceedance of interest. For example, $(\eta_c)_{p=0.05}$, where the subscript $p = 0.05$, indicates that 5 percent of the crest elevations exceed the value of η_c .

Assumed independent variables are significant wave height, H_s (defined as four times the rms water level, η_{rms}), period of peak energy density, T_p , water depth, d , and beach slope, m .

1. Irregular Wave Crest Elevations.

Figure 16 presents several irregular wave records illustrating various amounts of nonlinearity. Records A and B have crests which are slightly larger than half of their zero up-crossing wave heights; record C has crest elevations which are a large fraction of wave height. Table 6, which is a compilation of selected wave record results, indicates the elevation of maximum crests for various water depth, significant wave height, and period of peak energy density

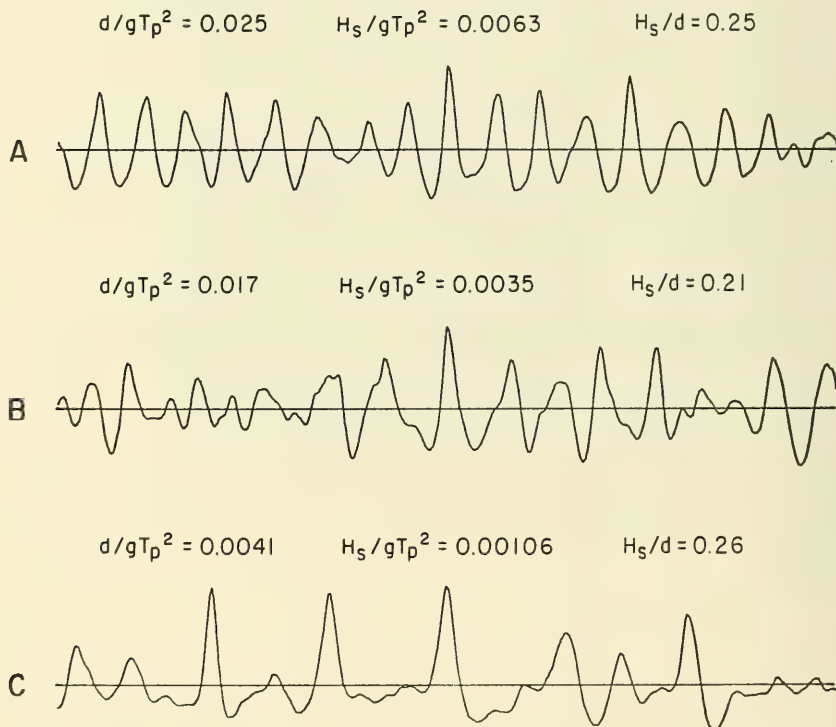


Figure 16. Sample of irregular wave time histories.

Table 6. Selected irregular wave crest elevation data.

Location	Date	Time	H_s/d	H_s/gT_p^2	d/gT_p^2	No. of waves	Highest crest observed		Source
							η_c/H_s	η_c/d	
Field Data									
Atlantic City, N.J.	2 Mar. 69	2001	0.47	0.0036	0.0078	60	1.088	0.51	Thompson (1980)
Atlantic City, N.J.	21 Jan. 69	1202	0.54	0.0032	0.0058	52	1.31	0.71	Thompson (1980)
Nags Head, N.C.	19 Oct. 72	1840	0.45	0.0055	0.012	106	0.897	0.40	Thompson (1980)
Lake Worth, Fla.	28 Mar. 71	0820	0.32	0.001	0.0031	72	1.65	0.53	Thompson (1980)
Gulf of Mexico	Hurricanes and storms		(Small?)	?	?	22,194	1.308	0.41	Jahns and Wheeler (1973)
Laboratory Data ($m = 0$)									
	17 Oct. 80	1404	0.084	0.00035	0.0042	288	1.71	0.14	This study
	17 Oct. 80	1241	0.285	0.00061	0.0021	300	1.63	0.47	This study
	17 Oct. 80	1427	0.27	0.00057	0.0021	300	1.406	0.38	This study
	6 Oct. 80	1257	0.122	0.0055	0.045	224	1.40	0.17	This study
	6 Oct. 80	1306	0.158	0.0053	0.0337	205	1.449	0.23	This study
	6 Oct. 80	1417	0.117	0.0057	0.049	236	1.28	0.15	This study

combinations. Thompson (1980) discussed several coastal gage records with large ratios of H_s/d that have η_c/H_s ratios on the order of one for the highest crest observed, while η_c/d for the largest crest is somewhat less than one. Jahns and Wheeler (1973) found similar extremes for hurricane and storm waves in the Gulf of Mexico. Large values of η_c/H_s can be obtained if the significant wave height is small compared to the water depth and the wave steepness is low. Individual wave crests with elevations greater than 1.5 times the significant wave height were observed in a number of the laboratory experiments, where $H_s/d < 0.3$ and $d/(gT_p^2) < 0.005$ for $m = 0.0$.

Similar values of maximum wave crest elevation were found for irregular waves shoaling on a 1 on 30 laboratory smooth slope. An examination of a typical set of results showed that crest elevation increases as the wave shoals, then decreases as the wave breaks (Fig. 17). Note that in this figure both the crest elevation and the stillwater depth have been normalized by the deepwater equivalent significant wave height, H_0 . Typical values of the single highest crest observed during an irregular wave test of 260 seconds for model time are presented in Table 7. Water level time histories at several gages at various depths along the 1 on 30 slope are given in Figure 18 for an irregular wave condition.

Jahns and Wheeler (1973) suggested a method for predicting irregular wave crest statistics, using the dimensionless parameter $(\eta_c)/H_s$. A Rayleigh-type distribution is assumed, then an empirical correction factor is recommended to increase the probability of occurrence of crests. One of the disadvantages of this approach is that the data often dramatically differ from a Rayleigh distribution because actual probabilities are orders of magnitude larger than predicted. For example, Figure 19 compares crest height distributions for the wave records A, B, and C shown in Figure 16 with the Rayleigh distribution.

The approach taken in this report is to predict crest elevations in terms of local parameters for a given probability level in terms of H_s , d , and T_p . Figure 20 shows values of η_c/d for wave records A, B, and C illustrated in Figure 16.

The suggested method for predicting irregular wave crest elevations is to use the stream-function results to determine the general form of the equation and laboratory results to calibrate the prediction technique for various probability levels. The equation used is

$$\frac{(\eta_c)_p}{H_s} = \frac{A_1^*}{1.0 + \tanh \left(-A_2 \ln \left(A_3 \frac{H_s}{L_0} \right) \right)} \quad (8)$$

where the parameters A_2 and A_3 are taken from stream-function results (Fig. 8 and Table 2), and A_1^* is an empirical parameter determined from the experimental data. The laboratory data (App. C) indicate that A_1^* is a function of the probability of exceedance, with A_1^* increasing as the probability, p , decreases (Fig. 21, Table 8). Equation (8) shows good correlation with the laboratory data as indicated by the small standard deviation of A_1^* about the mean for values of $p = 0.01$ and greater (Tables 8 and 9). A_1^* at $p = 0.005$ has poor resolution because the data collection runs had only a few crests more than 200 crests per run. Figure 22 gives observed and predicted crest elevations at the 2-percent probability level of exceedance.

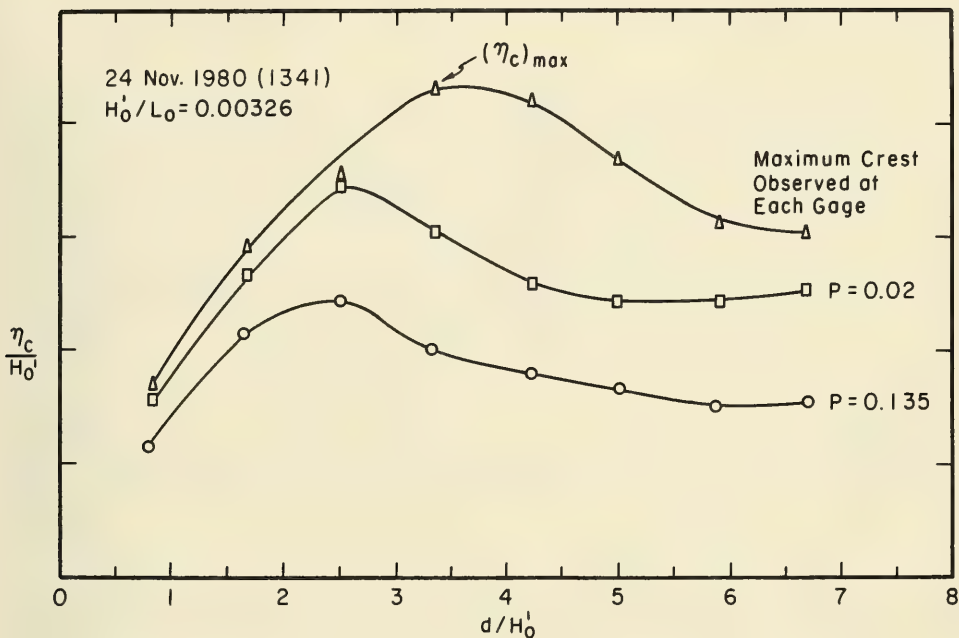


Figure 17. Variation in wave crest elevation for a 1 on 30 slope.

Table 7. Selected irregular wave crest data for waves breaking on a 1 on 30 slope.

Date	Time	H_0'/L_0	Wave and crest data at the occurrence of the highest single crest				
			H_s/d	d/gT_p^2	$(\eta_c)_{\max}/H_s$	$(\eta_c)_{\max}/d$	$(\eta_c)_{\max}/H_0'$
25 Nov. 80	1223	0.040	0.27	0.12	1.23	0.33	1.03
25 Nov. 80	1110	0.032	0.35	0.067	1.25	0.44	1.08
24 Nov. 80	1517	0.024	0.41	0.051	1.29	0.53	1.15
24 Nov. 80	1310	0.021	0.33	0.057	1.27	0.42	1.15
24 Nov. 80	1431	0.0115	0.38	0.031	1.60	0.60	1.60
24 Nov. 80	1259	0.0050	0.27	0.021	1.86	0.50	2.13
24 Nov. 80	1332	0.0033	0.29	0.014	1.75	0.51	2.16

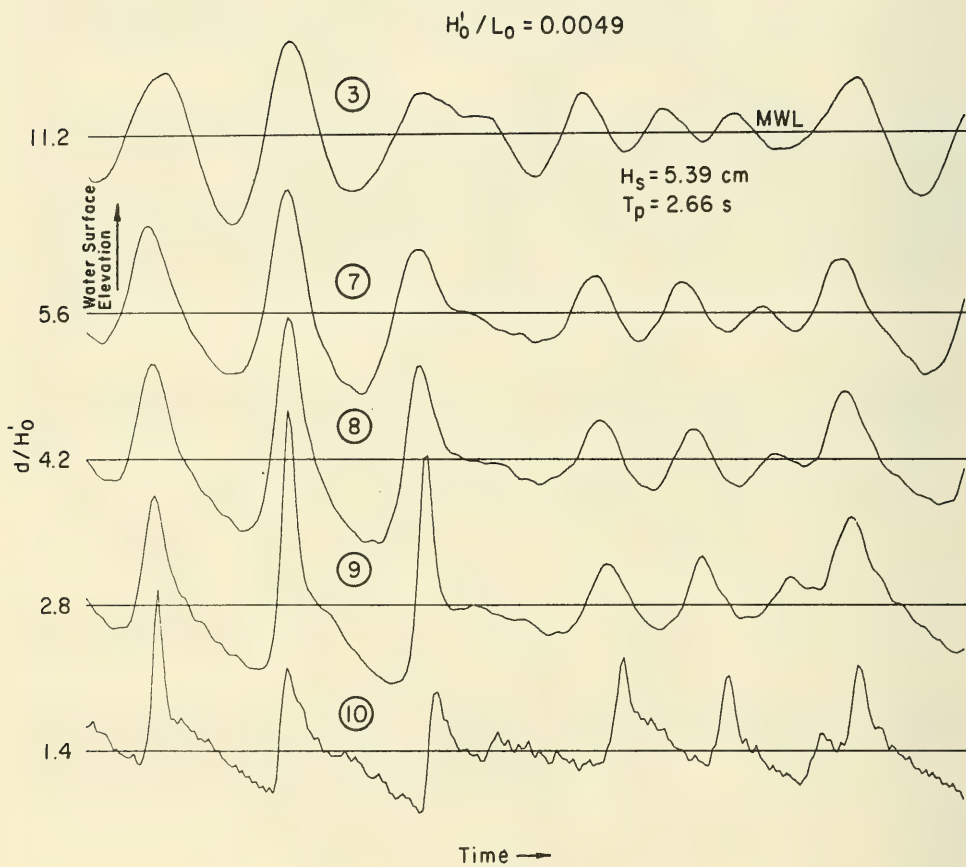


Figure 18. Sample of water level time histories for irregular waves at selected locations along a 1 on 30 slope.

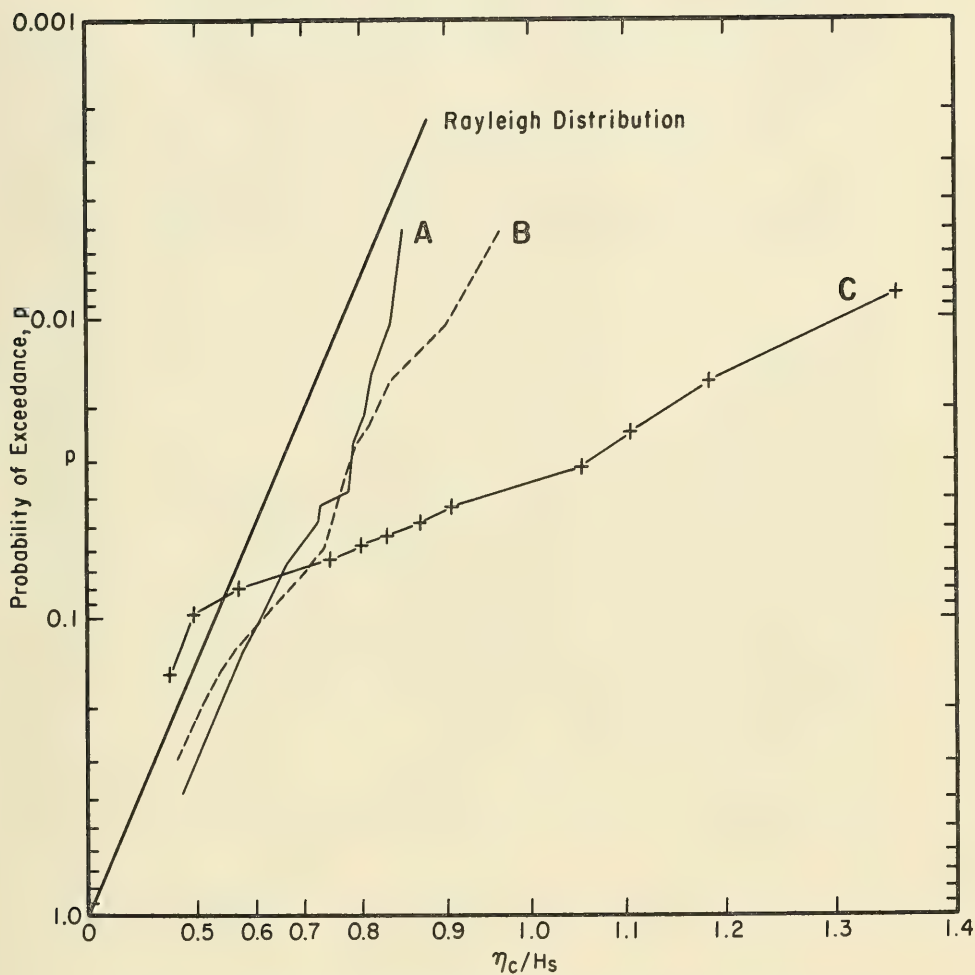


Figure 19. Sample of irregular wave crest elevation distributions (from wave records shown in Fig. 16).

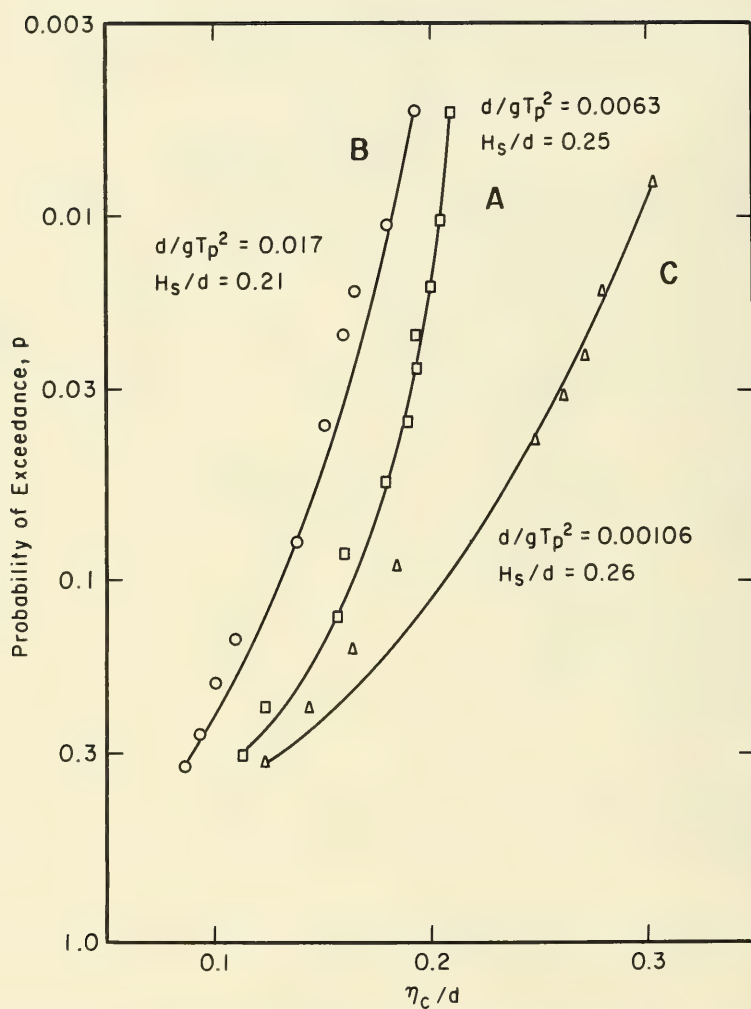


Figure 20. Sample of wave crest distributions (from wave records shown in Fig. 16).

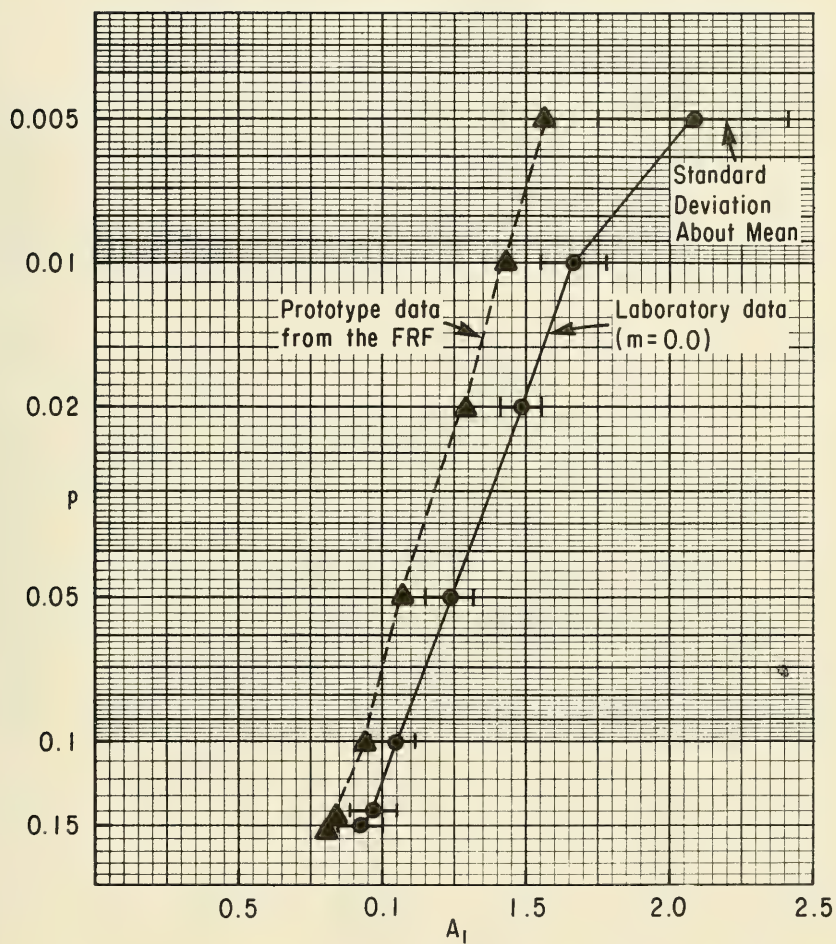


Figure 21. Values of A_1^* for probability of exceedance for irregular waves.

Table 8. Values of A_1^* for levels of probability of exceedance for irregular waves ($m = 0.0$), derived from 122 laboratory experiments.

Probability of exceedance, p	A_1^*	Std. dev. of A_1^*	Coefficient of variation (pct)
0.150	0.929	0.082	8.8
0.135	0.960	0.083	8.6
0.100	1.048	0.082	7.8
0.050	1.240	0.085	6.9
0.020	1.488	0.152	10.2
0.010	1.669	0.209	12.5
0.005	2.119	0.33	15.6

Table 9. Values of A_1^* for levels of probability of exceedance for irregular waves on a 1 on 30 laboratory slope ($m = 0.033$), derived from 192 laboratory measurements.

Probability of exceedance, p	A_1^*	Std. dev. of A_1^*	Coefficient of variation (pct)
0.150	0.919	0.058	6.3
0.135	0.948	0.061	6.4
0.100	1.029	0.075	7.3
0.050	1.20	0.099	8.2
0.020	1.46	0.176	12.1
0.010	1.70	0.285	16.8

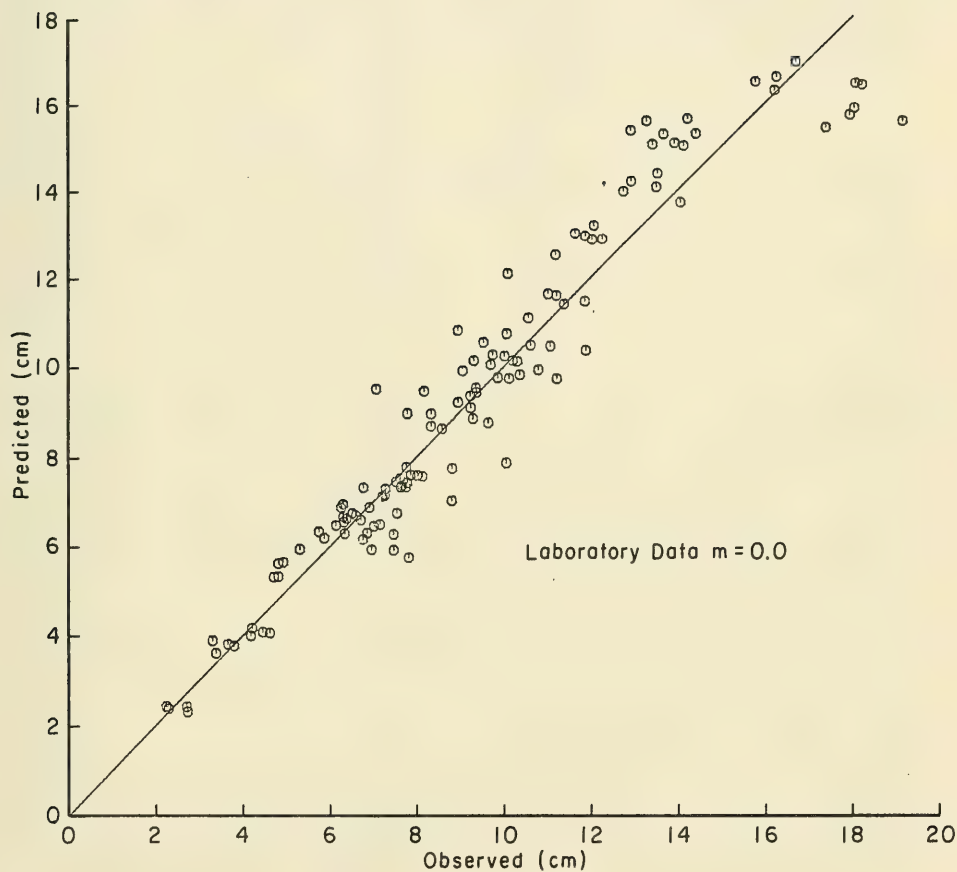


Figure 22. Observed and predicted crest elevations exceeded by 2 percent of the wave crests.

The wave crest elevation of irregular waves on a 1 on 30 slope may also be described in terms of deepwater wave characteristics. An examination of the data indicates that deepwater wave steepness and local stillwater depth control the magnitude of crest elevation at a given probability level. For example, Figure 23 presents the crest elevation exceeded by 13.5 percent of the wave crests for the deepwater wave steepness range $0.0035 < H'_0/L_0 < 0.0075$ for $m = 0.0333$ (a 1 on 30 slope with the experimental setup shown in Fig. 6). The irregular wave data show a consistent trend with crest elevation increasing in the shoaling region and decreasing after breaking.

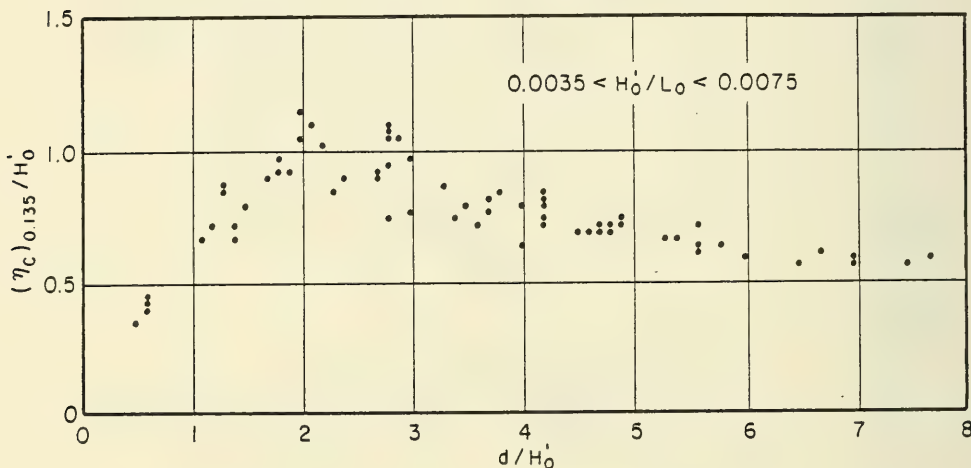


Figure 23. Wave crest elevation exceeded by 13.5 percent of the wave crests.

2. Crest Elevation Prediction Aids.

Irregular wave crest elevations may be predicted in terms of local wave conditions using equation (8). Figure 24 gives crest elevation exceeded by 2 percent of the wave crests ($p = 0.02$) normalized by the water depth. Curves of constant H_s/d are plotted with $d/(gT_p^2)$ on the abscissa. As a first estimate the upper limit of wave height is assumed to be given by equation (5) and the crest elevation of this condition is shown as a dashline. Figure 25 presents crest elevations exceeded by 13.5 percent of the wave crests. Figures 24 and 25 may be used for waves traveling over a flat bottom and for plane slopes as steep as 1 on 30.

Crest elevations are presented in terms of deepwater wave characteristics for incident waves normal to a 1 on 30 slope for the 2- and 13.5-percent probability of exceedance levels in Figure 26. These curves were determined using the laboratory data presented in Appendix D. A dashline is used to indicate a region of uncertainty.

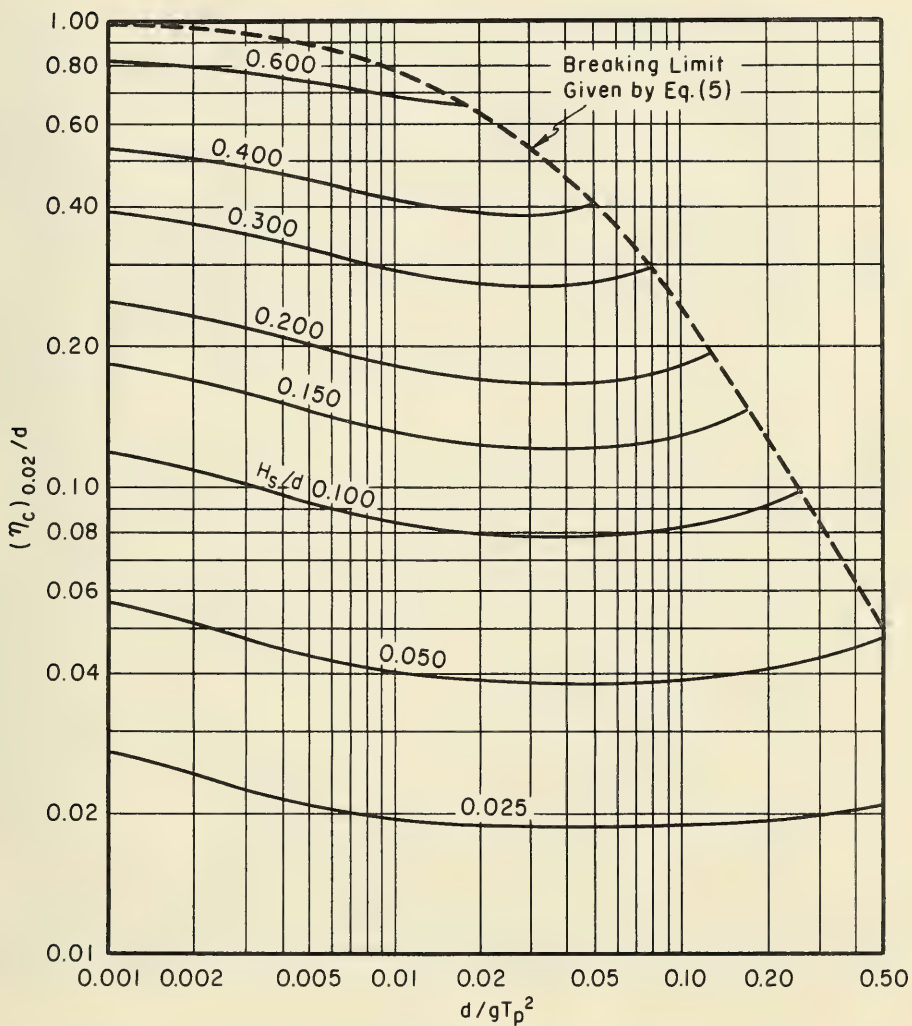


Figure 24. Crest elevation at the 2-percent probability level of exceedance for irregular waves.

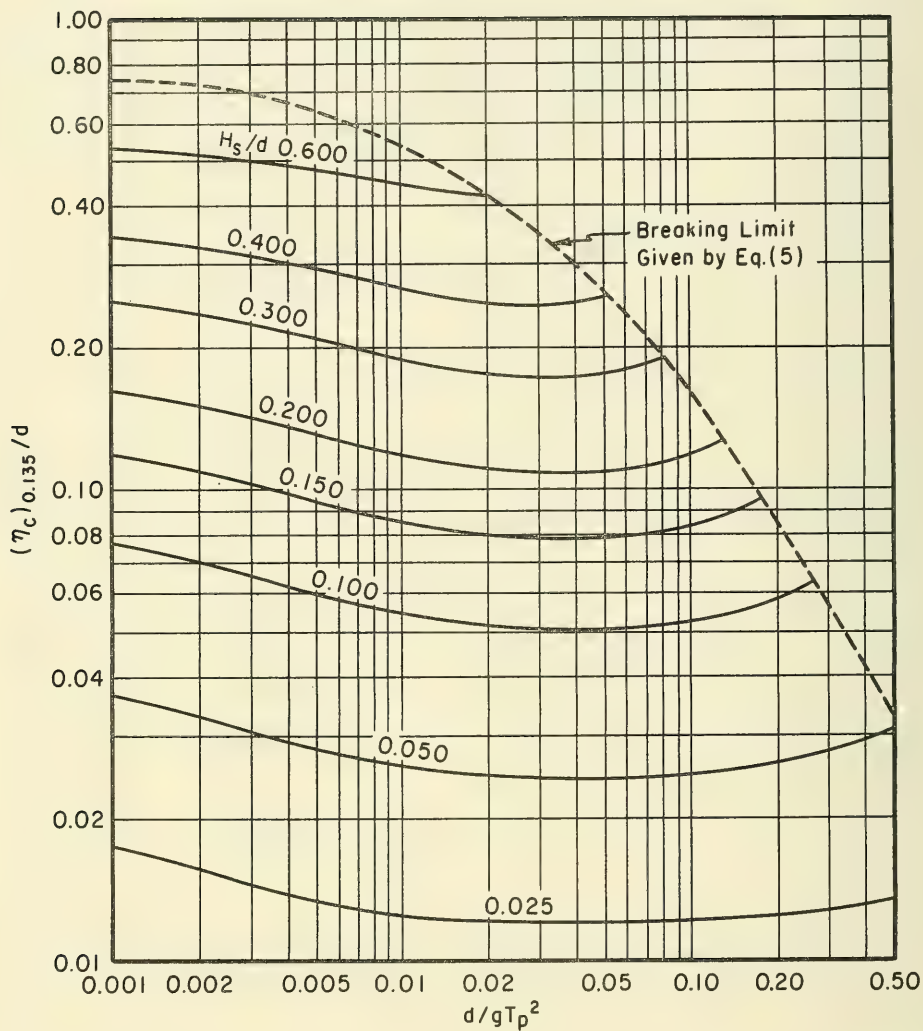


Figure 25. Crest elevation at the 13.5-percent probability level of exceedance for irregular waves.

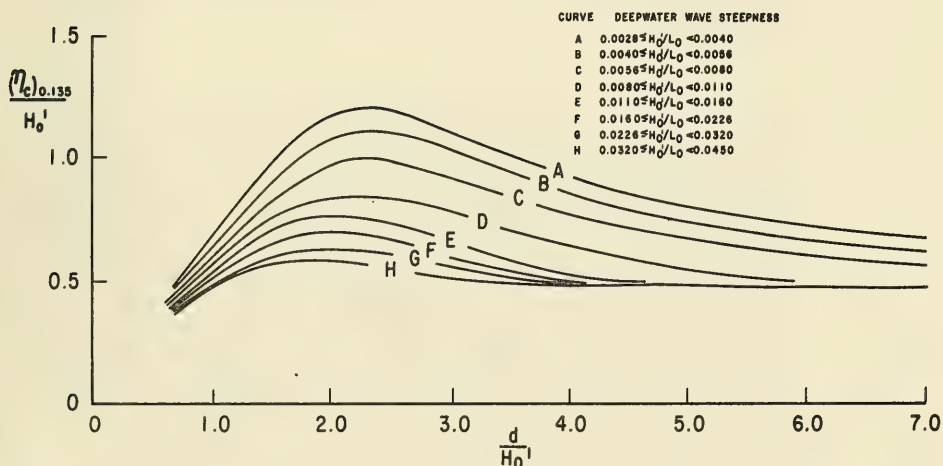
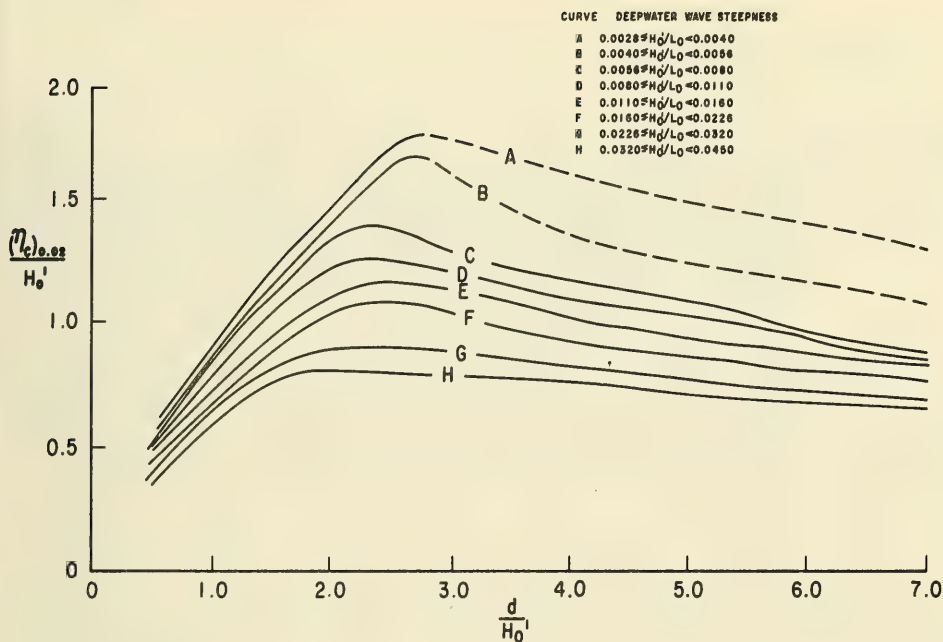


Figure 26. Wave crest elevations along a 1 on 30 slope for 2- and 13.5-percent probability of exceedance levels.

3. The Duration of Irregular Wave Crests.

The larger waves in an irregular wave train have the greatest nonlinearity, so the duration of the crests of these waves tends to be small relative to wave period. Figure 27 illustrates this trend by presenting the mean relative crest duration for various probability levels of exceedance for waves traveling over a flat bottom. For example, 5 percent of the largest crests have a mean dimensionless crest duration $T_c/T = 0.406$, while the average value for all of the wave crests (at the 100-percent level) have $T_c/T = 0.473$.

VI. COMPARISON OF RESULTS FOR PROTOTYPE DATA

The techniques presented in the previous section are to be used for the future prediction of wave characteristics in field situation. In this section, field data collected at the FRF in Duck, North Carolina, are analyzed in the same manner as the laboratory data previously described and comparisons are presented to demonstrate the applicability of the predictive techniques.

1. Field Conditions.

Four Waverider buoys were used to obtain the prototype data in an area where the bottom contours are essentially straight and parallel. Table 10 gives the locations of the gages and the mean water depths. The data were collected in the third week of October 1980 during a severe storm that produced wave heights exceeding 4 meters. The data set has widely varying significant wave height and period of peak energy density combinations resulting as the storm moved into and through the study area. Table 10 summarizes the range of wave conditions used in this report.

2. Prototype Verification.

The field data were analyzed in the same manner as the laboratory data used in formulating the predictive parameters. The observed crest elevations were compared with those predicted by equation (8), using values of A_1^* for $m = 0.0$ (Table 8), since the bottom slope was very gentle. Table 11 shows the results of this comparison for decreasing exceedance probabilities. It should be noted that the predicted crest elevations are slightly conservative, with the coefficient of variation approximately 8.5 percent. Figures 28 and 29 illustrate the predictive ability of equation (8); the diagonal line indicates perfect agreement. The scatter decreases for higher probability of exceedance levels, in part, because the data for higher probability levels are more statistically reliable. These figures also show that the scatter from the prediction line increases slightly as H_s/d increases. This increase in conservatism with increasing wave height-to-depth ratio may be due to the fact that the waves are interacting with a bottom that is slightly sloping and comprised of a porous sandy material (rather than a rigid floor used in the laboratory experiments). The directional characteristics of the prototype waves could also be influencing these results because a spectrum of wave directions was present, even though the primary wave direction was along the line of the Waveriders.

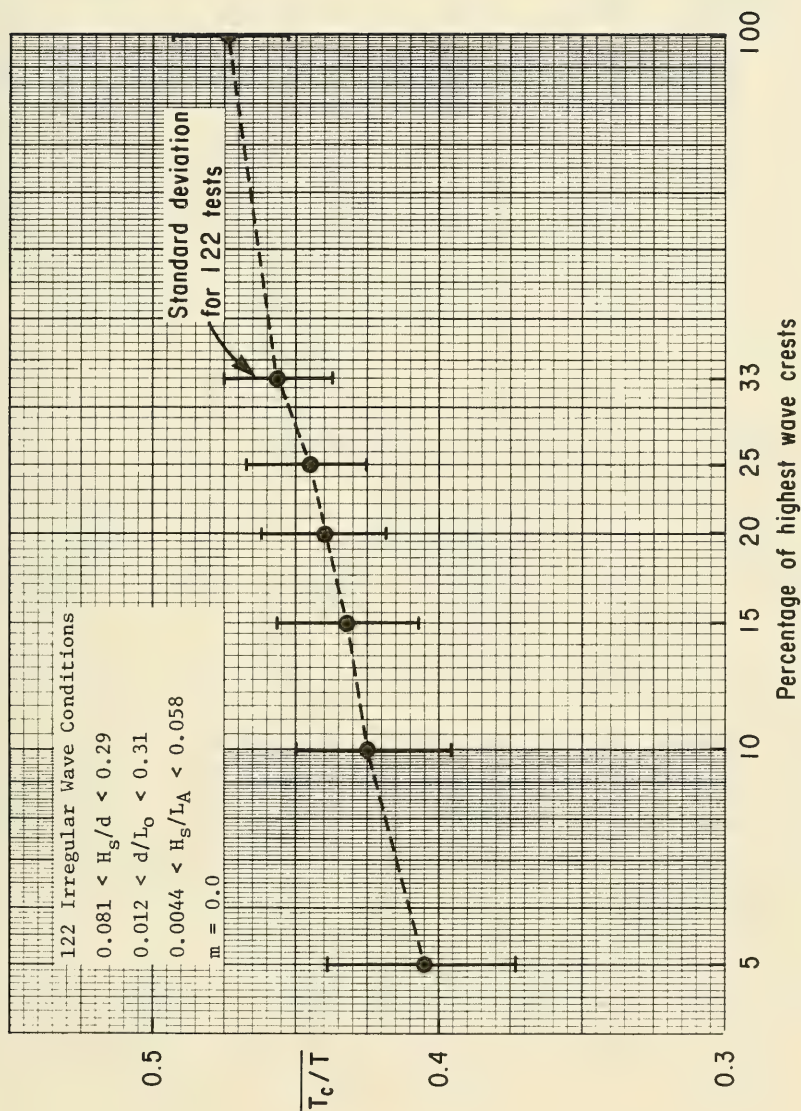


Figure 27. Dimensionless wave crest duration for irregular waves ($m = 0.0$).

Table 10. Summary of prototype wave conditions.

Waverider distance from shore (km)	Water depth (m)	H_s (m)		T_p (s)		Wave steepness	
		Max.	Min.	Max.	Min.	Max.	Min.
0.5	7	3.6	0.5	14	3	0.0641	0.0016
3.0	17	3.8	0.5	14	3	0.0570	0.0016
6.0	18	4.3	0.4	14	3	0.0570	0.0013
12.0	25	4.4	0.4	14	3	0.0570	0.0013

Table 11. Values of crest heights observed and predicted for waves at Duck, North Carolina.¹

Probability of exceedance	Mean ratio of observed and predicted crest elevations ²	A_1^* Observed	Coefficient of variation (pct)
0.150	0.912	0.847	8.5
0.135	0.909	0.873	8.3
0.100	0.902	0.945	8.6
0.050	0.877	1.087	8.7
0.020	0.861	1.281	8.6
0.010	0.848	1.415	9.0
0.005	0.729	1.545	11.6

¹Values derived from 100 20-minute wave records taken in October 1980.

²Values of A_1^* from Table 8 used to make predictions.

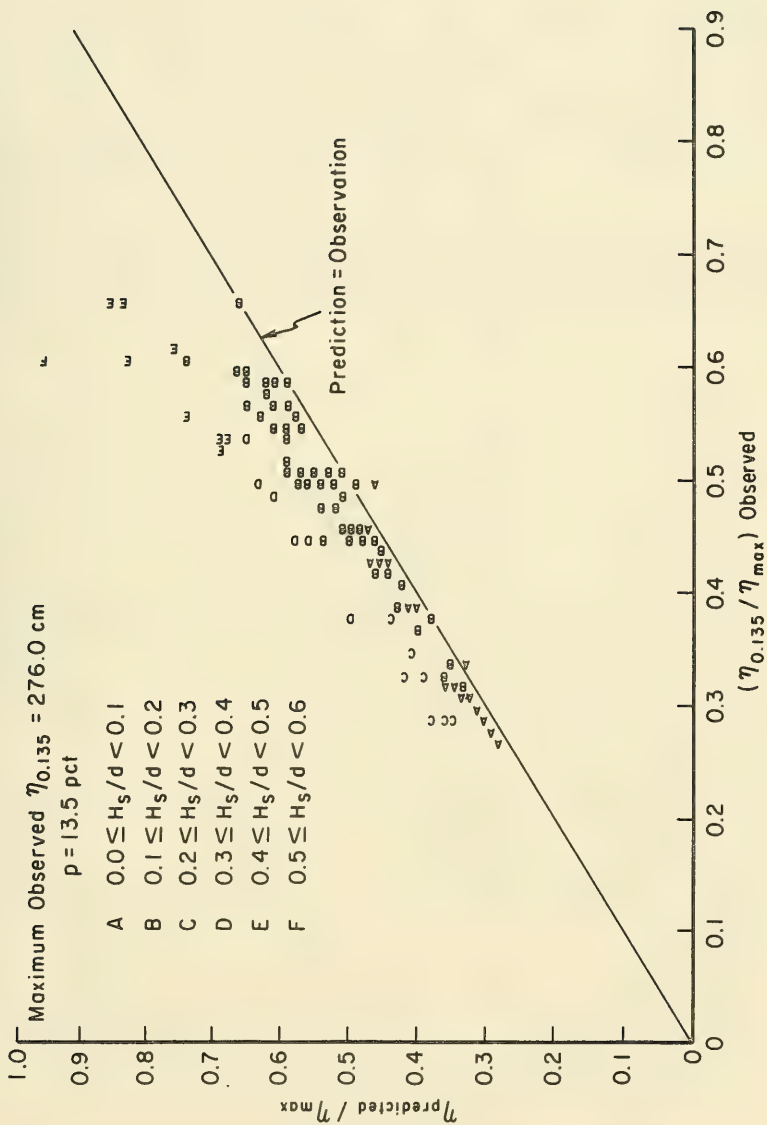


Figure 28. Observed versus predicted crest elevations ($p = 0.135$).

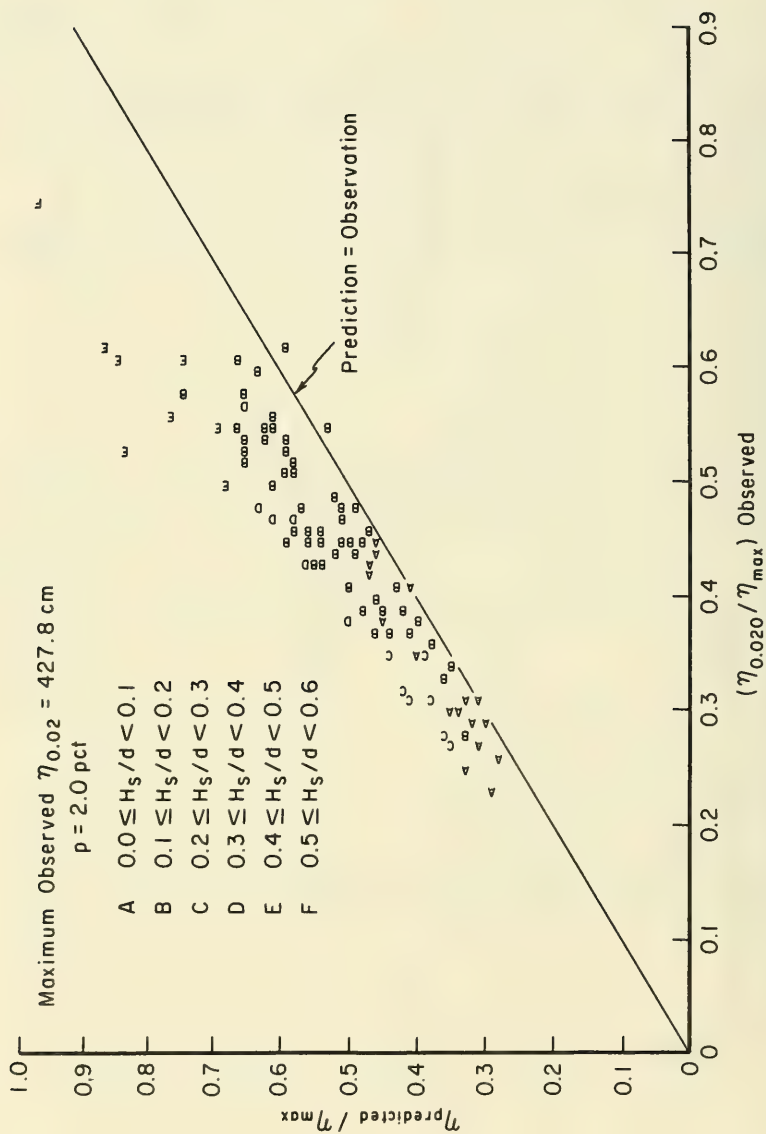


Figure 29. Observed versus predicted crest elevations ($p = 0.020$).

VII. SUMMARY AND CONCLUSIONS

The stream-function tables of Dean (1974) are used to develop empirical formulas for estimating monochromatic wave crest elevations and durations. The resulting formulas are calibrated with laboratory data. The method for predicting crest elevations was found to work well for waves traveling over a flat bottom or at the breaker point on plane smooth slopes. The equation for predicting crest elevations was calibrated for irregular wave conditions traveling over a flat bottom and shoaling on a 1 on 30 plane slope. The irregular wave data taken with the 1 on 30 slope were also expressed in terms of deepwater conditions and it was found that deepwater steepness and local water depth could be used to predict crest elevations.

Prediction equations developed from two-dimensional irregular laboratory waves were found to be conservative in predicting crest elevations when compared to field measurements taken at CERC's Field Research Facility, Duck, North Carolina. The conservatism is slight and increases with increasing H_s/d .

LITERATURE CITED

- BIESEL, F., "A Theoretical Study of a Certain Type of Wave Generator," *La Houille Blanche*, No. 4, 1951, pp. 475-496.
- BRETSCHNEIDER, C.L., "Selection of Design Wave for Offshore Structures," *Journal of the Waterways and Harbors Division*, Vol. WW 2, No. 1568, Mar. 1958.
- DEAN, R.G., "Evaluation and Development of Water Wave Theories for Engineering Application," SR-1, Vol. II, U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, Va., Nov. 1974.
- GODA, Y., "Wave Forces on a Vertical Circular Cylinder: Experiments and a Proposed Method of Wave Force Computation," Report No. 8, Port and Harbor Technical Research Institute, Ministry of Transportation, Japan, Aug. 1964.
- GODA, Y., "Irregular Wave Deformation in the Surf Zone," *Coastal Engineering in Japan*, Vol. 18, 1975, pp. 13-25.
- JAHS, H.O., and WHEELER, J.D., "Long-Term Wave Probabilities Based on Hind-casting of Severe Storms," *Journal of Petroleum Technology*, Apr. 1973, pp. 473-486.
- OCHI, M.K., and HUBBLE, E., "Six-Parameter Wave Spectra," *Proceedings of the 15th Conference on Coastal Engineering*, American Society of Civil Engineers, 1976, pp. 301-328.
- SINGAMSETTI, S.R., and WIND, H.G., "Characteristics of Shoaling and Breaking Periodic Waves Normally Incident to Plan Beaches of Constant Slope," Report M1371, Delft Hydraulics Laboratory, The Netherlands, July 1980.
- THOMPSON, E.F., "Wave Climate at Selected Locations Along U.S. Coasts," TR 77-1, U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, Va., Jan. 1977.
- THOMPSON, E.F., "Energy Spectra in Shallow U.S. Coastal Waters," TP 80-2, U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, Va., Feb. 1980.
- WEGGEL, J.R., "Wave Overtopping Equation," *Proceedings of the 15th Conference on Coastal Engineering*, American Society of Civil Engineers, 1976a, pp. 2737-2755.
- WEGGEL, J.R., "Cnoidal Wave Data," U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, Va., unpublished, Aug. 1976b.

APPENDIX A

MONOCHROMATIC TESTS RESULTS

BREAKING MONOCHROMATIC WAVE DATA
COT(M)= 5
DATA BY SINGAMSETTI AND WIND(1980)

HB(CM)	T(SEC)	DB(CM)	DB/LO	HB/LO	ETA C/H	TC/T
11.7	1.55	12.7	0.034	0.0311	0.568	0.411
19.3	1.55	15.6	0.041	0.0513	0.625	0.422
15.5	1.28	12.2	0.048	0.0606	0.663	0.408
9.6	1.28	10.2	0.040	0.0376	0.608	0.453
9.5	1.55	7.2	0.019	0.0252	0.654	0.412
10.5	1.04	8.0	0.048	0.0628	0.653	0.373
15.9	1.28	13.0	0.051	0.0621	0.645	0.407
9.0	1.04	7.7	0.046	0.0538	0.639	0.408
11.7	1.04	9.6	0.057	0.0696	0.675	0.419
18.3	1.72	19.3	0.042	0.0398	0.581	0.392
12.4	1.72	11.3	0.024	0.0270	0.628	0.424
16.2	1.28	13.6	0.053	0.0631	0.648	0.397
12.1	1.28	10.1	0.039	0.0471	0.674	0.440
8.9	1.28	8.0	0.031	0.0347	0.657	0.445
9.2	1.55	9.6	0.025	0.0246	0.619	0.402
8.7	1.04	8.0	0.047	0.0518	0.638	0.398
15.0	1.28	13.0	0.051	0.0582	0.615	0.370
7.7	1.04	9.7	0.058	0.0458	0.635	0.436
11.7	1.04	9.6	0.057	0.0699	0.638	0.400
18.3	1.72	19.2	0.042	0.0398	0.610	0.464
12.3	1.72	17.5	0.038	0.0268	0.586	0.498

SUM, SUM1, NO= 0.6720 1 0858 21
SD, SD1 =0.036970.09162
TC/T N, AVERAGE SD= 21 1.8236 0.3165

BREAKING MONOCHROMATIC WAVE DATA
COT(M)= 10
DATA BY SINGAMSETTI AND WIND(1980)

HB(CM)	T(SEC)	DB(CM)	DB/LO	HB/LO	ETA C/H	TC/T
13.7	1.55	12.7	0.034	0.0366	0.673	0.422
16.9	1.55	19.9	0.053	0.0451	0.740	0.292
11.7	1.28	12.8	0.050	0.0460	0.745	0.350
8.6	1.28	10.6	0.042	0.0336	0.727	0.367
11.1	1.55	10.1	0.027	0.0296	0.722	0.430
9.1	1.03	11.2	0.067	0.0545	0.739	0.326
13.5	1.28	14.4	0.056	0.0526	0.725	0.366
7.2	1.03	9.6	0.058	0.0434	0.678	0.342
10.5	1.03	12.7	0.076	0.0631	0.738	0.342
16.9	1.72	18.4	0.040	0.0367	0.729	0.323
14.0	1.72	11.4	0.025	0.0305	0.741	0.419
15.0	1.28	18.2	0.071	0.0587	0.755	0.331
14.1	1.55	12.8	0.034	0.0376	0.674	0.431
17.0	1.55	18.7	0.050	0.0454	0.000	0.000
11.8	1.28	13.0	0.051	0.0462	0.741	0.348
10.1	1.28	8.8	0.034	0.0395	0.728	0.306
11.9	1.55	10.5	0.028	0.0318	0.000	0.000
8.6	1.03	8.8	0.053	0.0520	0.743	0.339
14.3	1.28	17.1	0.067	0.0559	0.748	0.345
7.7	1.03	7.7	0.047	0.0468	0.719	0.361
11.2	1.03	13.3	0.080	0.0677	0.686	0.390
17.4	1.71	18.2	0.040	0.0383	0.752	0.373
14.0	1.71	12.2	0.027	0.0307	0.732	0.332
15.6	1.28	18.6	0.073	0.0610	0.734	0.314

SUM, SUM1, NO= 0.8181 1.2420 22
SD, SD1 =0.075200.08541
TC/T N, AVERAGE SD= 22 1.4007 0.4204

BREAKING MONOCHROMATIC WAVE DATA
 COT(M)= 20
 DATA BY SINGAMSETTI AND WIND(1980)

HB(CM)	T(SEC)	DB(CM)	DB/LO	HB/LO	ETA C/H	TC/T
14.0	1.55	17.0	0.045	0.0374	0.751	0.307
17.4	1.55	20.0	0.053	0.0464	0.745	0.309
11.4	1.28	12.5	0.049	0.0449	0.770	0.273
9.6	1.28	10.0	0.039	0.0379	0.782	0.274
10.5	1.55	10.1	0.027	0.0281	0.779	0.295
8.8	1.04	10.7	0.064	0.0521	0.756	0.325
13.5	1.28	17.2	0.068	0.0530	0.767	0.333
7.8	1.04	9.2	0.055	0.0467	0.778	0.330
10.0	1.04	12.8	0.076	0.0598	0.752	0.360
17.6	1.73	20.0	0.043	0.0377	0.756	0.322
13.2	1.73	12.4	0.027	0.0284	0.792	0.269
16.2	1.28	20.2	0.079	0.0638	0.741	0.331
14.2	1.55	15.2	0.040	0.0379	0.789	0.289
18.0	1.55	20.7	0.055	0.0482	0.758	0.293
11.8	1.28	13.4	0.053	0.0465	0.768	0.300
10.0	1.28	10.8	0.043	0.0394	0.804	0.277
10.5	1.55	10.2	0.027	0.0281	0.772	0.290
9.1	1.04	11.0	0.066	0.0544	0.747	0.298
13.2	1.28	15.7	0.061	0.0520	0.766	0.320
7.7	1.04	8.9	0.053	0.0458	0.751	0.314
10.1	1.04	12.6	0.075	0.0601	0.770	0.336
17.1	1.73	17.9	0.038	0.0366	0.805	0.286
13.1	1.73	12.5	0.027	0.0282	0.774	0.265
16.5	1.28	20.8	0.082	0.0648	0.784	0.328

SUM, SUM1, NO= 0.8806 1.3052 24
 SD, SD1 =0.082740.08863
 TC/T N, AVERAGE SD= 24 1.1256 0.1118

BREAKING MONOCHROMATIC WAVE DATA
 COT(M)= 40
 DATA BY SINGAMSETTI AND WIND(1980)

HB(CM)	T(SEC)	DB(CM)	DB/LO	HB/LO	ETA C/H	TC/T
13.6	1.55	14.5	0.039	0.0363	0.805	0.292
17.0	1.55	20.2	0.054	0.0453	0.783	0.302
11.9	1.28	13.9	0.055	0.0468	0.793	0.301
9.2	1.28	11.0	0.043	0.0364	0.779	0.240
11.1	1.55	11.7	0.031	0.0297	0.822	0.259
9.6	1.04	11.6	0.069	0.0571	0.751	0.328
7.9	1.04	9.2	0.055	0.0470	0.766	0.316
15.9	1.28	21.9	0.086	0.0625	0.758	0.311
13.6	1.28	15.0	0.059	0.0537	0.747	0.356
11.0	1.04	15.2	0.090	0.0654	0.750	0.366
12.4	1.04	16.8	0.100	0.0738	0.767	0.335
13.3	1.04	20.4	0.122	0.0791	0.718	0.349
13.1	1.72	14.9	0.032	0.0285	0.824	0.266
13.6	1.55	14.5	0.039	0.0363	0.798	0.277
16.8	1.55	21.2	0.056	0.0450	0.775	0.302
11.8	1.28	12.9	0.051	0.0464	0.741	0.354
9.1	1.28	10.1	0.040	0.0360	0.752	0.286
11.0	1.55	11.7	0.031	0.0295	0.823	0.274
9.5	1.04	12.6	0.075	0.0565	0.761	0.324
7.7	1.04	9.2	0.055	0.0461	0.790	0.301
15.9	1.28	19.4	0.076	0.0627	0.722	0.375
13.2	1.28	16.4	0.065	0.0519	0.772	0.309
10.9	1.04	14.2	0.084	0.0648	0.697	0.316
12.5	1.04	16.3	0.097	0.0744	0.759	0.338
13.7	1.04	16.4	0.116	0.0815	0.738	0.337
14.0	1.72	15.4	0.033	0.0303	0.822	0.270

MONOCHROMATIC WAVE TEST (M=0.0)-
SINUSOIDAL BLADE MOTION

H(CM)	T(SEC)	D(CM)	D/LO	H/LO	ETA C/H	TC/T
5.47	1.79	50.	0.100	0.0110	0.539	
9.07	1.79	50.	0.100	0.0181	0.567	
12.66	1.79	50.	0.100	0.0253	0.587	
16.27	1.79	50.	0.100	0.0326	0.600	
19.68	1.79	50.	0.100	0.0394	0.601	
3.33	0.96	50.	0.348	0.0232	0.517	
6.57	0.96	50.	0.348	0.0457	0.534	
8.11	0.96	50.	0.348	0.0564	0.545	
9.63	0.96	50.	0.348	0.0670	0.540	
10.96	0.96	50.	0.348	0.0762	0.554	
12.23	0.96	50.	0.348	0.0851	0.570	
13.44	0.96	50.	0.348	0.0935	0.576	
14.65	0.96	50.	0.348	0.1019	0.579	
6.05	3.03	50.	0.035	0.0042	0.626	
7.41	3.03	50.	0.035	0.0052	0.647	
8.85	3.03	50.	0.035	0.0062	0.665	
10.34	3.03	50.	0.035	0.0072	0.680	
11.83	3.03	50.	0.035	0.0083	0.694	
13.31	3.03	50.	0.035	0.0093	0.706	
14.88	3.03	50.	0.035	0.0104	0.716	
16.53	3.03	50.	0.035	0.0115	0.728	
18.14	3.03	50.	0.035	0.0127	0.734	
3.36	0.80	50.	0.501	0.0337	0.521	
4.99	0.80	50.	0.501	0.0500	0.546	
6.65	0.80	50.	0.501	0.0666	0.555	
8.06	0.80	50.	0.501	0.0807	0.565	
9.34	0.80	50.	0.501	0.0936	0.567	
10.51	0.80	50.	0.501	0.1052	0.580	
5.31	2.53	50.	0.050	0.0053	0.590	
6.71	2.53	50.	0.050	0.0067	0.602	
8.16	2.53	50.	0.050	0.0082	0.613	
10.40	2.53	50.	0.050	0.0104	0.625	
12.67	2.53	50.	0.050	0.0127	0.629	
14.20	2.53	50.	0.050	0.0142	0.637	
16.57	2.53	50.	0.050	0.0166	0.639	
19.00	2.53	50.	0.050	0.0190	0.645	
5.88	4.00	50.	0.020	0.0024	0.688	
7.63	4.00	50.	0.020	0.0031	0.609	
9.44	4.00	50.	0.020	0.0038	0.636	
11.29	4.00	50.	0.020	0.0045	0.657	
13.23	4.00	50.	0.020	0.0053	0.673	
12.38	4.00	50.	0.020	0.0050	0.683	
11.32	4.00	50.	0.020	0.0045	0.697	
12.44	4.00	50.	0.020	0.0050	0.693	
8.26	1.27	50.	0.199	0.0328	0.545	
13.41	1.27	50.	0.199	0.0533	0.580	
17.00	1.27	50.	0.199	0.0676	0.562	
20.61	1.27	50.	0.199	0.0819	0.621	
6.89	1.27	50.	0.199	0.0274	0.538	
5.61	5.66	50.	0.010	0.0011	0.527	

H(CM)	T(SEC)	D(CM)	D/LO	H/LO	ETA C/H	TC/T
6.27	5.66	50.	0.010	0.0013	0.539	
7.27	5.66	50.	0.010	0.0015	0.537	
8.34	5.66	50.	0.010	0.0017	0.547	
9.45	5.66	50.	0.010	0.0019	0.569	
11.90	5.66	50.	0.010	0.0024	0.599	
13.77	5.66	50.	0.010	0.0028	0.616	
15.60	5.66	50.	0.010	0.0031	0.631	
17.11	5.66	50.	0.010	0.0034	0.641	
1.64	1.60	60.	0.150	0.0041	0.520	0.481
7.16	1.60	60.	0.150	0.0179	0.543	0.475
10.90	1.60	60.	0.150	0.0273	0.551	0.476
15.37	1.60	60.	0.150	0.0385	0.585	0.449
20.05	1.60	60.	0.150	0.0502	0.592	0.448
1.81	1.75	60.	0.126	0.0038	0.511	0.494
6.28	1.75	60.	0.126	0.0131	0.542	0.472
8.57	1.75	60.	0.126	0.0179	0.563	0.460
11.38	1.75	60.	0.126	0.0238	0.581	0.454
16.24	1.75	60.	0.126	0.0340	0.603	0.432
2.80	1.96	60.	0.100	0.0047	0.524	0.489
10.52	1.96	60.	0.100	0.0176	0.599	0.438
14.93	1.96	60.	0.100	0.0249	0.629	0.411
20.67	1.96	60.	0.100	0.0345	0.673	0.395
26.08	1.96	60.	0.100	0.0435	0.716	0.373
1.63	2.27	60.	0.075	0.0020	0.518	0.490
7.90	2.27	60.	0.075	0.0093	0.578	0.455
10.99	2.27	60.	0.075	0.0137	0.601	0.442
15.27	2.27	60.	0.075	0.0190	0.629	0.418
21.73	2.27	60.	0.075	0.0270	0.655	0.380
2.72	2.77	60.	0.050	0.0023	0.523	0.488
7.79	2.77	60.	0.050	0.0065	0.575	0.450
11.18	2.77	60.	0.050	0.0093	0.617	0.414
16.45	2.77	60.	0.050	0.0137	0.648	0.375
23.16	2.77	60.	0.050	0.0193	0.716	0.336
29.31	2.77	60.	0.050	0.0245	0.761	0.322
1.79	5.06	60.	0.015	0.0004	0.523	0.485

APPENDIX B

IRREGULAR WAVE CREST ELEVATIONS

IRREGULAR WAVE CREST ELEVATIONS (LAH DATA)										
D/(G*T ²)	HS/(G*T ²)	H(CM)	HS(CM)	TP(SEC)	ETA C/HS FOR PROBABILITY LEVELS=					
					P=0.15	0.135	0.10	0.05	0.02	0.01 0.005
.0251	.00627	60.0	14.97	1.56	.563	.578	.631	.720	.792	.828
.0251	.00624	60.0	14.90	1.56	.567	.557	.614	.654	.822	.879
.0257	.00691	60.0	16.10	1.54	.589	.616	.669	.756	.837	.847
.0257	.00686	60.0	16.00	1.54	.582	.561	.598	.685	.796	.826
.0066	.00069	60.0	6.29	3.05	.533	.545	.588	.716	.767	.779
.0066	.00066	60.0	5.98	3.05	.524	.536	.588	.721	.789	.806
.0061	.00107	60.0	9.94	3.16	.535	.541	.591	.689	.710	.871
.0061	.00096	60.0	9.45	3.16	.531	.566	.666	.733	.824	1.045
.0173	.00346	60.0	12.01	1.88	.548	.586	.628	.705	.811	.907
.0173	.00341	60.0	11.86	1.88	.547	.558	.601	.728	.869	.906
.0048	.00099	60.0	12.22	3.56	.579	.598	.680	.799	.915	1.036
.0048	.00096	60.0	11.86	3.56	.596	.616	.666	.727	.851	.919
.0041	.00106	60.0	15.58	3.88	.642	.687	.707	.929	1.071	1.139
.0041	.00104	60.0	15.29	3.88	.640	.658	.762	.873	1.062	1.090
.0270	.00687	60.0	15.26	1.51	.557	.575	.638	.708	.790	.807
.0270	.00673	60.0	14.95	1.51	.564	.570	.599	.764	.804	1.024
.0216	.00585	60.0	16.25	1.68	.579	.589	.650	.729	.831	.887
.0216	.00578	60.0	16.07	1.68	.561	.582	.604	.713	.803	.884
.0057	.00058	60.0	6.17	3.28	.523	.533	.563	.743	.799	.811
.0057	.00055	60.0	5.86	3.28	.531	.539	.589	.754	.824	.848
.0173	.00345	60.0	11.98	1.88	.558	.570	.611	.745	.836	.919
.0173	.00342	60.0	11.87	1.88	.528	.557	.610	.715	.859	.865
.0200	.00522	45.0	11.74	1.51	.578	.598	.648	.731	1.011	1.132
.0200	.00503	45.0	11.31	1.51	.545	.550	.588	.683	.801	.885
.0147	.00399	45.0	12.19	1.77	.593	.607	.656	.747	.866	.956
.0147	.00391	45.0	11.94	1.77	.529	.542	.597	.650	.750	.888
.0065	.00062	45.0	4.30	2.67	.518	.543	.567	.792	.853	.888
.0065	.00059	45.0	4.09	2.67	.516	.539	.583	.756	.832	.893
.0099	.00185	45.0	8.41	2.15	.535	.554	.585	.664	.952	1.090
.0099	.00179	45.0	8.14	2.15	.526	.548	.601	.693	.832	.881
.0033	.00071	45.0	9.60	3.71	.653	.688	.764	.905	1.152	1.190
.0033	.00071	45.0	9.07	3.61	.672	.678	.709	.875	1.115	1.126
.0035	.00096	45.0	12.26	3.61	.656	.693	.761	.908	1.145	1.185
.0035	.00092	45.0	11.70	3.61	.688	.702	.734	.878	.994	1.123
.0045	.00095	45.0	9.54	3.20	.605	.619	.661	.828	1.132	1.172
.0020	.00040	45.0	9.19	4.83	.584	.610	.717	.872	1.095	1.234
.0062	.00092	45.0	6.72	2.72	.577	.581	.640	.723	.856	.869
.0062	.00087	45.0	6.35	2.72	.535	.556	.592	.721	.835	.850
.0183	.00383	75.0	17.89	2.17	.530	.572	.684	.802	1.082	1.105
.0157	.00367	75.0	17.50	2.21	.543	.573	.643	.772	.993	1.111

00350 00354	000045 000043	75.0 75.0	17.94 17.68	1.47 1.46	0590 0574	0596 0596	0624 0634	0691 0718	0761 0758	0928 0901
00273 00273	000645 000546	75.0 75.0	19.07 19.11	1.67 1.67	0617 0560	0635 0577	0699 0600	0799 0716	0947 0825	1.050 0926
00006 00006	000043 000009	75.0 75.0	8.05 7.76	2.98 2.98	0544 0556	0555 0572	0580 0622	0655 0673	0784 0814	0834 0842
00200 00210	000370 000303	75.0 75.0	13.85 13.70	1.95 1.91	0553 0518	0576 0538	0590 0593	0672 0718	0795 0865	0948 0947
00056 00056	000115 000115	75.0 75.0	15.57 15.53	3.71 3.71	0601 0605	0640 0610	0652 0659	0603 0769	0911 0854	1.093 1.013
00157 00152	000376 000359	75.0 75.0	17.95 17.72	2.21 2.25	0545 0536	0568 0573	0665 0652	0752 0827	1.005 1.012	1.084 1.078
00354 00354	000046 000032	75.0 75.0	17.95 17.66	1.47 1.47	0595 0576	0601 0587	0624 0634	0696 0698	0802 0799	0842 0853
00273 00273	000643 000609	75.0 75.0	19.02 18.91	1.67 1.67	0601 0562	0644 0577	0696 0617	0795 0735	0957 0857	1.007 0980
00066 00163	000042 000106	75.0 75.0	7.99 7.70	2.98 2.72	0532 0551	0542 0559	0611 0620	0694 0692	0784 0797	0845 0851
00066 00066	000135 000131	75.0 75.0	11.74 11.33	2.98 2.98	0580 0537	0590 0549	0622 0612	0764 0698	0812 0821	0893 0885
00200 00200	000309 000364	75.0 75.0	13.81 13.81	1.95 1.95	0544 0511	0558 0527	0587 0581	0689 0734	0811 0835	0899 0939
00064 00066	000131 000114	75.0 75.0	15.39 15.33	3.46 3.71	0643 0596	0658 0604	0682 0658	0799 0771	0902 0841	1.098 1.015
00374 00374	000420 000415	75.0 75.0	8.41 8.32	1.43 1.43	0556 0492	0582 0503	0611 0564	0680 0637	0759 0760	0821 0816
00439 00439	000443 000467	75.0 75.0	8.23 7.97	1.32 1.32	0541 0529	0553 0542	0595 0581	0695 0682	0868 0936	1.010 1.070
00354 00449	000444 000434	75.0 75.0	9.50 9.32	1.47 1.48	0524 0544	0535 0551	0586 0598	0688 0685	0802 0822	0879 1.002
00435 00434	000505 000557	75.0 75.0	9.75 9.51	1.33 1.32	0545 0530	0569 0545	0621 0580	0701 0666	0796 0855	0893 1.075
00354 00354	000520 000514	75.0 75.0	10.91 10.77	1.46 1.46	0525 0544	0536 0553	0598 0596	0733 0784	0883 0796	0968 0905
00491 00491	000557 000546	75.0 75.0	8.51 8.34	1.25 1.25	0566 0553	0596 0561	0630 0620	0721 0702	0886 0804	1.009 0.947
00453 00453	000558 000544	75.0 75.0	9.23 9.01	1.30 1.30	0528 0511	0535 0523	0567 0565	0643 0663	0839 0807	1.037 1.031
00354 00354	000525 000516	75.0 75.0	11.81 11.81	1.51 1.51	0541 0533	0563 0553	0608 0578	0660 0639	0793 0795	0840 0.995
00341 00341	000532 000548	75.0 75.0	12.13 12.03	1.50 1.50	0537 0514	0573 0527	0628 0583	0706 0672	0854 0932	1.063 1.235
00354 00374	000542 000544	75.0 75.0	8.02 7.90	1.46 1.43	0544 0507	0587 0523	0614 0588	0683 0692	0790 0744	0897 0775

00439	000480	75.0	8.19	1.32	546	562	620	720	856	1.004	1.170
00439	000469	75.0	8.01	1.32	513	521	549	713	855	0.952	1.070
00349	000438	75.0	9.39	1.48	524	548	606	761	828	0.926	1.038
00349	000430	75.0	9.23	1.48	508	528	567	709	789	0.948	1.134
00335	000554	75.0	9.55	1.33	551	578	624	684	823	0.919	0.999
00339	000549	75.0	9.37	1.32	522	534	557	671	803	1.001	1.223
00338	000525	75.0	11.02	1.46	549	566	606	765	843	0.992	1.285
00338	000517	75.0	10.84	1.46	548	559	597	689	789	0.974	
00441	000578	75.0	8.84	1.25	584	591	640	732	996	1.100	1.288
00441	000567	75.0	8.67	1.25	548	564	596	668	797	1.099	1.242
00453	000558	75.0	9.23	1.30	527	534	570	633	827	1.027	1.269
00453	000543	75.0	8.98	1.30	514	528	564	656	803	0.835	1.368
00334	000520	75.0	11.70	1.51	564	573	623	663	801	0.877	1.397
00334	000509	75.0	11.45	1.51	514	536	589	668	782	1.028	1.473
00341	000515	75.0	11.30	1.50	539	565	636	730	818	0.902	1.342
00341	000508	75.0	11.16	1.50	540	570	597	665	746	1.043	1.406
00034	000043	30.0	3.82	2.99	573	584	651	726	870	0.966	1.018
00032	000039	30.0	3.68	2.08	565	616	678	777	1.035	1.066	1.092
00033	000068	30.0	6.16	2.05	570	585	676	858	1.070	1.184	1.332
00028	000056	30.0	6.06	2.32	566	603	696	815	1.075	1.238	1.354
00020	000059	30.0	8.68	2.88	606	627	703	941	1.223	1.309	1.500
00023	000064	30.0	8.44	2.68	633	683	756	974	1.149	1.431	1.606
00042	000035	30.0	2.53	2.71	492	532	579	970	913	1.064	1.172
00028	000023	30.0	2.43	2.28	545	556	627	781	928	1.128	1.149
00042	000056	30.0	4.04	2.71	590	606	683	874	1.037	1.191	1.323
00028	000037	30.0	3.95	2.30	585	599	717	858	1.069	1.266	1.366
00077	000160	30.0	8.24	1.99	518	542	652	899	1.196	1.280	1.396
00077	000156	30.0	8.08	1.99	586	598	717	872	1.285	1.465	1.583
00022	000057	30.0	7.96	2.76	613	634	695	902	1.026	1.292	1.487
00075	000195	30.0	7.83	2.02	650	692	759	937	1.125	1.238	1.377
00039	000053	30.0	4.05	2.80	503	532	641	828	1.103	1.266	1.349
00031	000041	30.0	3.94	2.12	544	554	660	865	1.133	1.183	1.267
00041	000035	30.0	2.57	2.72	451	476	539	739	1.063	1.330	1.626
00042	000034	30.0	2.46	2.71	481	491	550	794	1.115	1.274	1.534
00078	000169	30.0	8.47	1.98	617	645	722	677	1.004	1.101	1.217

N# 119
N# 771

N# 806GT1,0GT2,FH# 10000E=02 20000E=02 38273E+00
B1,P2,PMS E# 80000E+01 80000E+00 88561E+03

N# 1010GT1,0GT2,FH# 20000E=02 40000E=02 45006E=01
B1,P2,PMS E# 80000E+01 80000E+00 45697E+06

N# 170GT1,0GT2,FH# 40000E=02 80000E=02 85638E=02
R1,B2,PMS E# 80000E+01 80000E+00 62273E+06

N# 790GT1,0GT2,FH# 80000E=02 16000E=01 31639E=01

APPENDIX C

IRREGULAR WAVE CREST DURATIONS

IRREGULAR WAVE AVERAGE DIMENSIONLESS CREST DURATIONS											
D/(G+T2)	H8/(G+T2)	H(CM)	H3(CM)	TP(SEC)	AVERAGE TC/1						
					P=1.00	0.33	0.25	0.20	0.15	0.10	0.05
.0251	.00627	60.0	10.97	1.56	.434	.432	.424	.423	.415	.400	.401
.0251	.00624	60.0	10.90	1.56	.435	.426	.426	.427	.424	.416	.400
.0257	.00641	60.0	10.10	1.54	.436	.422	.414	.407	.394	.383	.369
.0257	.00666	60.0	16.00	1.54	.444	.438	.424	.417	.413	.405	.387
.0064	.00069	60.0	6.29	1.05	.452	.450	.448	.444	.440	.433	.427
.0066	.00066	60.0	5.96	1.05	.454	.458	.457	.455	.460	.480	.428
.0061	.00102	60.0	9.90	1.16	.450	.450	.449	.442	.441	.446	.439
.0061	.00046	60.0	4.45	1.16	.462	.442	.434	.434	.425	.437	.444
.0173	.00346	60.0	12.01	1.88	.457	.444	.436	.425	.407	.379	.383
.0173	.00341	60.0	11.86	1.88	.466	.466	.462	.463	.436	.436	.400
.0046	.00044	60.0	12.22	1.56	.465	.452	.445	.432	.428	.433	.428
.0049	.00046	60.0	11.86	1.56	.455	.456	.427	.432	.425	.386	.380
.0041	.00106	60.0	15.58	1.88	.443	.440	.439	.426	.423	.379	.298
.0041	.00104	60.0	15.24	1.88	.460	.460	.421	.416	.389	.372	.325
.0270	.00687	60.0	15.26	1.51	.433	.424	.411	.407	.404	.399	.391
.0270	.00673	60.0	10.95	1.51	.433	.431	.426	.421	.418	.411	.382
.0216	.00585	60.0	16.25	1.88	.431	.416	.412	.404	.396	.383	.374
.0216	.00578	60.0	16.07	1.88	.430	.426	.415	.411	.407	.393	.384
.0057	.00058	60.0	8.17	1.28	.463	.461	.456	.450	.447	.440	.419
.0057	.00055	60.0	5.86	1.28	.460	.460	.454	.442	.445	.439	.423
.0173	.00345	60.0	11.98	1.88	.456	.445	.426	.420	.411	.388	.367
.0173	.00342	60.0	11.87	1.88	.456	.456	.448	.441	.427	.416	.422
.0200	.00422	45.0	11.78	1.51	.433	.424	.404	.402	.390	.380	.356
.0200	.00403	45.0	11.51	1.51	.447	.443	.434	.430	.417	.401	.386
.0147	.00349	45.0	12.19	1.77	.438	.436	.422	.413	.393	.376	.349
.0147	.00341	45.0	11.94	1.77	.456	.450	.419	.420	.418	.422	.396
.0065	.00062	45.0	4.30	1.67	.460	.460	.450	.451	.450	.438	.430
.0065	.00059	45.0	4.69	1.67	.453	.455	.455	.444	.445	.427	.424
.0099	.00185	45.0	8.41	1.15	.472	.471	.475	.485	.472	.463	.408
.0099	.00179	45.0	8.14	1.15	.480	.480	.488	.488	.456	.458	.465
.0031	.00071	45.0	9.60	1.71	.421	.421	.412	.395	.371	.366	.378
.0035	.00071	45.0	9.07	1.61	.447	.451	.424	.421	.401	.350	.367
.0035	.00096	45.0	12.26	1.61	.451	.444	.430	.426	.427	.412	.366
.0035	.00092	45.0	11.70	1.61	.444	.452	.449	.457	.452	.461	.406
.0045	.00095	45.0	9.54	1.20	.462	.462	.457	.451	.443	.423	.374
.0020	.00040	45.0	8.19	1.83	.466	.466	.466	.460	.429	.443	.399
.0062	.00092	45.0	6.72	1.72	.439	.441	.435	.426	.429	.435	.433
.0062	.00067	45.0	6.35	1.72	.437	.438	.422	.424	.431	.419	.421
.0163	.00383	75.0	17.69	1.17	.480	.446	.438	.417	.408	.393	.352
.0157	.00367	75.0	17.50	1.21	.487	.456	.425	.414	.407	.390	.376

0354 0358	000A45 000043	750 750	17.94 17.68	1.47 1.46	476 491	431 440	426 426	422 424	414 412	406 395	370 355
0273 0273	000645 000046	750 750	19.07 19.11	1.67 1.67	465 499	422 446	401 430	391 423	387 429	376 416	359 346
0066 0066	000093 000089	750 750	8.05 7.76	2.98 2.98	488 501	468 469	466 464	468 448	446 450	449 448	459 430
0200 0210	000370 000383	750 750	13.65 13.70	1.95 1.91	478 503	450 468	438 462	437 453	425 438	414 417	407 395
0050 0050	000115 000115	750 750	15.97 15.95	1.71 1.71	472 486	450 439	412 420	403 420	373 397	376 382	354 379
0157 0152	000376 000359	750 750	17.95 17.72	2.21 2.25	479 486	438 453	427 441	423 435	395 433	391 409	370 364
0354 0354	000A46 000A32	750 750	17.95 17.66	1.47 1.47	473 487	433 442	425 436	418 431	408 422	406 410	403 414
0273 0273	000A43 000689	750 750	19.07 18.91	1.67 1.67	460 494	421 440	411 433	397 426	386 423	373 414	358 381
0000 0103	000042 000106	750 750	7.99 7.70	2.98 2.72	494 497	470 461	444 459	446 441	450 442	445 445	453 433
0000 0000	000135 000131	750 750	11.74 11.33	2.98 2.98	483 496	444 456	436 451	432 427	440 427	424 421	419 416
0200 0200	000309 000304	750 750	13.81 13.61	1.95 1.95	476 506	463 474	457 463	457 450	426 443	403 403	407 391
0006 0056	000131 000114	750 750	15.34 15.33	1.46 1.71	464 492	448 436	422 412	409 415	396 418	373 407	351 391
0174 0174	000020 000015	750 750	8.01 8.12	1.43 1.43	483 498	466 478	457 470	461 469	451 462	442 454	440 449
0439 0439	000483 000487	750 750	8.23 7.97	1.32 1.32	478 486	467 462	456 451	442 452	432 445	432 437	432 425
0354 0354	000448 000434	750 750	9.50 9.32	1.47 1.48	483 480	480 457	477 447	475 445	475 431	453 414	458 410
0435 0439	000565 000557	750 750	9.75 9.51	1.33 1.32	486 495	480 465	447 452	447 452	440 453	437 430	436 409
0354 0354	000520 000514	750 750	10.91 10.77	1.46 1.46	481 496	470 460	471 454	469 452	455 445	452 442	425 421
0491 0491	000557 000546	750 750	8.51 8.34	1.25 1.25	482 488	453 450	447 442	441 437	444 439	441 441	433 432
0453 0453	000558 000544	750 750	9.23 9.01	1.30 1.30	497 494	477 464	481 460	472 459	463 454	448 451	442 423
0334 0334	000525 000516	750 750	11.81 11.61	1.51 1.51	475 495	456 471	450 459	447 449	445 444	439 435	424 411
0301 0341	000552 000548	750 750	12.13 12.03	1.50 1.50	476 514	454 464	442 460	434 455	432 442	424 427	417 408
0354 0374	000582 000594	750 750	8.02 7.90	1.46 1.43	484 493	473 483	461 469	453 455	444 457	441 443	429 419

00419 00449	0000440 000449	75.0 75.0	8.14 8.01	1.12 1.12	4491 4506	4445 4478	4467 4474	4456 4463	4452 4457	4451 4440	4441 4430
00349 00349	000438 000430	75.0 75.0	9.39 9.23	1.48 1.48	4491 4435	4462 4461	4469 4458	4459 4446	4454 4440	4453 4444	4463 4414
00435 00439	000554 000549	75.0 75.0	9.55 9.37	1.33 1.32	4491 4497	4457 4461	4450 4460	4449 4458	4446 4462	4436 4446	4424 4442
00358 00358	000525 000517	75.0 75.0	11.02 10.84	1.46 1.46	4475 4495	4464 4467	4459 4451	4464 4453	4455 4450	4443 4452	4431 4435
00491 00491	000578 000567	75.0 75.0	8.84 8.67	1.25 1.25	4481 4492	4451 4460	4440 4450	4438 4443	4435 4444	4431 4440	4421 4430
00453 00453	000558 000543	75.0 75.0	9.23 8.98	1.30 1.30	4496 4504	4472 4467	4468 4461	4461 4469	4458 4454	4457 4443	4437 4437
00334 00334	000520 000509	75.0 75.0	11.70 11.45	1.51 1.51	4474 4494	4456 4472	4449 4457	4445 4452	4442 4447	4438 4442	4437 4418
00341 00341	000515 000508	75.0 75.0	11.30 11.16	1.50 1.50	4476 4502	4439 4466	4430 4450	4427 4456	4424 4446	4435 4440	4409 4423
00034 00032	000043 000039	30.0 30.0	3.82 3.68	2.99 3.08	4494 4458	4424 4425	4427 4417	4423 4422	4404 4417	4394 4409	4387 4382
00033 00028	000068 000056	30.0 30.0	6.16 6.06	3.05 3.32	4484 4470	4429 4444	4423 4430	4427 4437	4395 4414	4373 4380	4365 4358
00020 00023	000059 000064	30.0 30.0	8.68 8.44	3.88 3.68	4452 4444	4415 4465	4449 4454	4466 4441	4447 4416	4433 4420	4378 4326
00042 00028	000035 000023	30.0 30.0	2.53 2.43	2.71 3.28	4495 4464	4457 4462	4460 4450	4447 4441	4433 4439	4444 4444	4407 4424
00042 00028	000056 000037	30.0 30.0	2.64 3.45	2.71 3.30	4494 4465	4440 4433	4424 4413	4418 4409	4400 4379	4381 4370	4361 4348
00077 00077	000160 000156	30.0 30.0	6.24 6.08	1.99 1.99	4485 4467	4455 4464	4426 4437	4420 4444	4400 4449	4438 4423	4391 4379
00022 00075	000057 000145	30.0 30.0	7.96 7.83	3.76 2.02	4465 4451	4490 4454	4484 4446	4471 4439	4457 4441	4441 4429	4402 4375
00044 00031	000053 000041	30.0 30.0	4.05 3.94	2.80 3.12	4492 4479	4467 4445	4454 4430	4445 4415	4435 4415	4410 4404	4417 4400
00041 00042	000035 000034	30.0 30.0	2.57 2.46	2.72 2.71	4490 4471	4483 4471	4472 4465	4465 4454	4463 4444	4460 4431	4460 4426
00078 00078	000169 000163	30.0 30.0	6.47 6.26	1.98 1.98	4468 4461	4498 4496	4472 4485	4481 4466	4479 4443	4490 4443	4529 4416
00021 00080	000058 000214	30.0 30.0	8.17 8.01	3.79 1.95	4458 4442	4520 4494	4497 4498	4503 4501	4494 4495	4471 4473	4429 4477

APPENDIX D

IRREGULAR WAVE DATA FOR SHOALING CONDITIONS

WAVE CREST ELEVATION WITH A 1/30 PLANE SLOPE

ID	SEASON	TP(S)	HS(CM)	D(CM)	CREST ELEVATION/MS							
					P= 0.15	0.135	0.10	0.05	0.02	0.01	0.005	
R011251110 157 10												
2	1.30	8.62	60.0	.535	.551	.604	.679	.757	.795	.818		
3	1.30	8.49	60.0	.518	.528	.567	.669	.773	.888	1.026		
4	1.46	8.35	60.0	.529	.543	.580	.647	.723	.759	.945		
5	1.46	8.29	52.5	.533	.555	.570	.665	.731	.803	.842		
6	1.43	8.04	45.0	.534	.546	.587	.682	.796	.874	1.012		
7	1.43	7.87	37.5	.523	.535	.555	.670	.845	.882	.954		
8	1.43	7.60	30.0	.561	.577	.613	.715	.791	.880	.937		
9	1.43	7.95	22.5	.569	.604	.693	.798	.939	1.011	1.226		
10	1.55	7.60	15.0	.691	.703	.763	.874	.948	1.048	1.056		
11	1.58	5.22	7.5	.740	.745	.796	.887	.998	1.060	1.135		
R011251118 257 10												
2	1.32	8.93	60.0	.526	.552	.575	.629	.794	.886	.976		
3	1.32	8.80	60.0	.507	.518	.557	.654	.853	.998	1.060		
4	1.12	8.67	60.0	.518	.547	.589	.686	.858	.879	1.004		
5	1.32	8.59	52.5	.554	.582	.607	.697	.871	.971	.992		
6	1.32	8.38	45.0	.530	.546	.593	.722	.841	.926	1.043		
7	1.32	8.21	37.5	.542	.574	.649	.739	.917	.941	1.056		
8	1.32	8.00	30.0	.566	.624	.655	.752	.881	.918	.980		
9	1.32	7.96	22.5	.575	.604	.712	.790	.943	1.001	1.010		
10	1.32	7.41	15.0	.693	.711	.741	.812	.920	.943	1.011		
11	1.48	5.11	7.5	.721	.729	.765	.826	.944	1.039	1.109		
R011251129 357 10												
2	1.48	9.53	60.0	.570	.591	.597	.653	.749	.815	.881		
3	1.37	9.40	60.0	.542	.547	.581	.722	.765	.837	.942		
4	1.41	9.29	60.0	.537	.553	.581	.712	.795	.839	.961		
5	1.41	9.25	52.5	.554	.561	.592	.709	.778	.884	.912		
6	1.41	9.06	45.0	.545	.553	.610	.733	.870	.938	.944		
7	1.57	8.93	37.5	.547	.555	.604	.726	.783	.830	1.047		
8	1.53	8.97	30.0	.597	.614	.660	.735	.845	.880			
9	1.57	9.10	22.5	.636	.657	.732	.864	.950	.993			
10	1.75	8.36	15.0	.745	.757	.791	.865	.954	1.026			
11	1.86	5.36	7.5	.724	.733	.758	.860	.934	1.001			
R011251138 457 5												
2	1.21	5.16	60.0	.490	.510	.548	.656	.768	.808	.845		
3	1.32	5.06	60.0	.513	.526	.563	.646	.762	.862	.908		
4	1.32	5.01	60.0	.510	.524	.547	.606	.742	.918	.977		
5	1.32	4.95	52.5	.499	.511	.569	.684	.777	.935	1.071		
6	1.32	4.80	45.0	.494	.516	.557	.648	.750	.840	.914		
7	1.32	4.66	37.5	.528	.557	.600	.699	.768	.832	.874		
8	1.32	4.70	30.0	.576	.518	.552	.632	.731	.790	.960		
9	1.32	4.76	22.5	.546	.553	.572	.704	.845	.949	1.013		
10	1.32	4.74	15.0	.613	.628	.692	.751	.933	.981	1.073		
11	1.42	4.44	7.5	.747	.773	.803	.883	.937	.994	1.013		
R011251147 457 5												
2	1.32	9.68	60.0	.515	.551	.590	.696	.803	.861	.903		
3	1.32	9.57	60.0	.540	.555	.601	.704	.860	.911	.921		
4	1.32	9.37	60.0	.547	.555	.597	.687	.832	1.006	1.095		
5	1.32	9.28	52.5	.542	.552	.590	.679	.738	.908	1.197		
6	1.32	9.16	45.0	.556	.571	.601	.704	.899	.934	1.154		
7	1.32	9.00	37.5	.532	.554	.595	.731	.956	1.145	1.192		
8	1.32	8.89	30.0	.556	.583	.627	.766	.905	1.053	1.097		
9	1.32	8.78	22.5	.616	.627	.696	.758	.911	1.030	1.097		
10	1.33	7.91	15.0	.695	.736	.781	.838	.923	.947	1.002		
11	1.60	5.25	7.5	.705	.716	.746	.872	1.031	1.087	1.123		
R011251156 557 5												
2	1.46	5.42	60.0	.501	.526	.563	.645	.726	.777	.790		
3	1.46	5.39	60.0	.503	.506	.548	.657	.715	.790	.836		
4	1.46	5.30	60.0	.506	.523	.590	.706	.766	.782	.939		
5	1.46	5.27	52.5	.524	.537	.570	.639	.744	.855	1.082		
6	1.41	5.17	45.0	.514	.519	.570	.629	.806	.934			
7	1.41	5.08	37.5	.497	.514	.596	.687	.797	.834	.975		
8	1.41	5.07	30.0	.523	.516	.638	.710	.814	.873	.876		
9	1.41	5.21	22.5	.552	.562	.609	.701	.925	1.008	1.033		
10	1.70	5.24	15.0	.652	.666	.727	.806	1.023	1.045			
11	1.53	4.59	7.5	.603	.612	.633	.693	1.006	1.055	1.184		

R0112512 5 557 5

2	1.46	10.79	60.0	.554	.560	.628	.766	.834	.874	1.021
3	1.46	10.54	60.0	.521	.547	.630	.711	.827	.944	1.187
4	1.46	10.39	60.0	.546	.564	.614	.722	.862	1.082	1.126
5	1.46	10.39	52.5	.532	.551	.642	.752	.840	.853	
6	1.46	10.15	45.0	.571	.541	.604	.686	.659	.934	.985
7	1.46	10.13	37.5	.554	.574	.642	.747	.900	1.040	
8	1.46	10.05	30.0	.584	.610	.666	.702	.999	1.012	
9	1.46	8.93	22.5	.652	.660	.720	.822	.954	.977	
10	1.52	8.99	15.0	.743	.755	.776	.852	.689	.961	
11	8.83	5.45	7.5	.722	.727	.777	.667	.951	1.000	

R011251223 657 5

2	1.25	9.07	60.0	.526	.538	.566	.621	.693	1.018	1.114
3	1.25	8.93	60.0	.515	.534	.552	.644	.913	1.068	1.086
4	1.25	8.83	60.0	.528	.544	.595	.672	.796	.871	.989
5	1.25	8.72	52.5	.550	.560	.602	.731	.816	.876	.886
6	1.25	8.40	45.0	.516	.533	.588	.677	.928	1.092	1.124
7	1.25	8.25	37.5	.552	.559	.602	.724	.922	1.081	1.105
8	1.25	8.09	30.0	.579	.591	.645	.706	.882	.982	1.179
9	1.23	7.92	22.5	.674	.687	.725	.764	.924	.976	.999
10	1.23	7.32	15.0	.715	.720	.750	.850	.966	.947	.995
11	1.53	4.92	7.5	.725	.738	.761	.839	.677	.938	1.044

R011251233 757 5

2	1.30	9.33	60.0	.511	.522	.568	.710	.834	1.022	1.196
3	1.30	9.26	60.0	.543	.548	.574	.684	.766	.888	1.175
4	1.30	9.04	60.0	.561	.574	.611	.677	.617	.961	1.165
5	1.30	8.97	52.5	.561	.572	.604	.666	.601	1.033	1.236
6	1.30	8.76	45.0	.539	.556	.610	.706	.793	1.064	1.148
7	1.30	8.59	37.5	.550	.572	.645	.729	.832	1.020	1.244
8	1.30	8.47	30.0	.577	.589	.634	.751	.908	1.043	1.145
9	1.30	8.41	22.5	.614	.640	.707	.840	.967	1.020	1.237
10	1.30	7.62	15.0	.714	.722	.745	.819	.999	.966	1.005
11	9.14	5.05	7.5	.715	.735	.770	.849	.932	.944	1.057

R011251245 857 5

2	1.46	8.21	60.0	.471	.484	.517	.603	.799	1.231	1.359
3	1.46	8.16	60.0	.473	.486	.510	.576	.974	1.116	1.354
4	1.46	8.10	60.0	.467	.489	.524	.573	.720	1.136	1.308
5	1.46	8.06	52.5	.504	.511	.547	.590	.820	1.206	1.211
6	1.46	5.92	45.0	.478	.500	.540	.558	.968	1.171	1.585
7	1.46	5.87	37.5	.476	.494	.535	.642	1.227	1.491	1.506
8	1.46	5.90	30.0	.483	.514	.543	.615	1.125	1.519	
9	1.52	5.92	22.5	.523	.539	.571	.680	1.244	1.591	
10	1.54	5.52	15.0	.660	.690	.735	.819	.957	1.165	
11	1.54	4.78	7.5	.787	.796	.836	.873	.989	1.081	

R0112513 6 657 6

2	1.52	9.56	60.0	.513	.520	.589	.725	.834	1.044	1.294
3	1.52	9.48	60.0	.524	.550	.604	.661	.793	1.109	1.374
4	1.52	9.38	60.0	.525	.535	.595	.666	.811	.893	1.266
5	1.52	9.32	52.5	.516	.524	.556	.623	.830	1.312	
6	1.52	9.14	45.0	.520	.534	.572	.651	.820	1.226	
7	1.52	9.04	37.5	.523	.529	.573	.680	.889	1.177	
8	1.52	8.87	30.0	.553	.564	.619	.699	.978	1.176	
9	1.52	8.74	22.5	.617	.630	.676	.774	.921	1.023	
10	1.54	8.11	15.0	.724	.766	.790	.820	.878	.895	
11	1.57	5.26	7.5	.675	.698	.747	.841	1.032	1.102	

R0112510 1 645 10

2	1.77	12.81	60.0	.581	.590	.627	.725	.833	.900	
3	1.77	12.73	60.0	.526	.563	.614	.661	.798	.895	
4	1.77	12.62	60.0	.526	.536	.566	.660	.726	.816	
5	1.77	12.64	52.5	.551	.561	.630	.705	.784	.844	
6	1.77	12.55	45.0	.600	.620	.635	.702	.746	.837	
7	1.77	12.52	37.5	.611	.627	.661	.730	.945	1.039	
8	1.77	12.31	30.0	.654	.662	.713	.767	.907	.968	
9	1.77	11.96	22.5	.751	.763	.790	.884	.909	.939	
10	2.03	9.83	15.0	.792	.806	.825	.871	.959	1.014	
11	2.39	6.03	7.5	.665	.672	.721	.886	1.007	1.041	

R011251010 645 5

2	1.79	8.26	60.0	.516	.537	.568	.622	.709	.752	
3	1.77	8.18	60.0	.526	.554	.582	.642	.799	.908	
4	1.79	8.13	60.0	.473	.482	.551	.653	.785	.847	
5	1.78	8.13	52.5	.508	.516	.564	.675	.751	.796	
6	1.79	8.09	45.0	.536	.546	.566	.641	.684	.629	
7	1.78	8.09	37.5	.531	.550	.570	.645	.761	.833	
8	1.67	8.12	30.0	.539	.554	.621	.711	.794	.855	
9	1.67	8.35	22.5	.627	.640	.690	.746	.786	.909	
10	2.03	8.39	15.0	.731	.753	.831	.918	1.012	1.048	
11	2.03	4.91	7.5	.815	.824	.872	.964	1.024	1.126	

R011251020 745 5

2	3.51	6.68	60.0	.560	.615	.664	.772	.949	.994
3	3.46	6.54	60.0	.590	.604	.623	.754	.912	.999
4	3.46	6.57	60.0	.520	.530	.597	.788	.934	1.094
5	3.46	6.66	52.5	.547	.576	.625	.745	.869	1.091
6	3.51	6.79	45.0	.557	.564	.585	.703	.832	1.073
7	3.46	6.90	37.5	.548	.550	.575	.736	.856	1.047
8	3.66	7.10	30.0	.603	.626	.660	.722	1.013	1.161
9	3.71	7.64	22.5	.705	.715	.780	.957	1.099	1.292
10	4.27	7.73	15.0	.860	.884	1.040	1.160	1.396	1.474
11	3.88	5.62	7.5	.797	.811	.869	.966	1.055	1.148

R011251024 745 10

2	3.71	14.03	60.0	.659	.688	.748	.904	1.154	1.202
3	3.46	13.91	60.0	.640	.650	.758	.881	1.099	1.179
4	3.46	13.63	60.0	.571	.630	.690	.857	.945	1.274
5	3.46	13.42	52.5	.650	.661	.712	.803	.881	1.302
6	3.66	14.12	45.0	.596	.657	.705	.804	.881	1.172
7	3.41	14.32	37.5	.665	.673	.688	.916	1.102	1.213
8	3.41	14.69	30.0	.765	.780	.841	1.020	1.213	1.290
9	3.71	14.09	22.5	.809	.817	.893	1.069	1.257	1.294
10	3.88	11.18	15.0	.741	.815	.848	.963	1.129	1.135
11	11.13	8.19	7.5	.625	.636	.697	.778	.870	.925

R011241517 345 5

2	1.67	9.54	60.0	.532	.552	.575	.681	.730	.860
3	1.67	9.35	60.0	.534	.546	.591	.677	.838	.900
4	1.67	9.29	60.0	.520	.546	.596	.647	.833	.946
5	1.67	9.27	52.5	.505	.527	.575	.673	.814	.975
6	1.67	9.15	45.0	.549	.559	.599	.706	.797	.921
7	1.67	9.03	37.5	.546	.610	.608	.721	.843	1.105
8	1.67	9.10	30.0	.571	.578	.614	.715	.858	1.234
9	1.67	9.15	22.5	.713	.722	.765	.900	1.019	1.117
10	1.67	8.47	15.0	.611	.623	.868	.942	1.050	1.091
11	1.83	5.48	7.5	.736	.704	.800	.905	.981	1.064

R01125 942 545 10

2	3.12	10.56	60.0	.524	.546	.638	.860	.989	1.156
3	3.12	10.59	60.0	.500	.512	.666	.854	1.059	
4	3.12	10.49	60.0	.573	.576	.654	.798	1.006	1.092
5	3.12	10.70	52.5	.600	.624	.671	.832	1.000	
6	3.12	10.83	45.0	.615	.643	.680	.793	1.070	
7	3.12	11.18	37.5	.681	.706	.746	.891	1.221	1.229
8	3.12	11.33	30.0	.731	.672	.973	1.060	1.387	1.473
9	3.12	10.95	22.5	.904	.941	1.031	1.104	1.251	
10	3.33	9.27	15.0	.654	.676	.963	1.102	1.208	1.239
11	15.06	6.83	7.5	.613	.647	.732	.872	1.028	1.300

R01125 951 545 8

2	3.16	8.33	60.0	.512	.526	.607	.775	.918	1.091
3	3.16	8.33	60.0	.504	.533	.634	.800	.985	1.010
4	3.16	8.28	60.0	.546	.544	.637	.773	.925	
5	3.16	8.44	52.5	.573	.586	.640	.819	.940	
6	3.16	8.55	45.0	.585	.605	.629	.804	1.049	
7	3.16	8.76	37.5	.635	.648	.708	.885	1.148	
8	3.16	8.43	30.0	.692	.757	.674	.972	1.340	
9	3.16	9.14	22.5	.651	.910	1.043	1.291	1.402	1.567
10	3.37	8.01	15.0	.699	.918	1.022	1.149	1.236	1.267
11	15.06	6.03	7.5	.682	.777	.605	.956	1.036	1.265

R011241439 145 5

2	2.17	8.20	60.0	.468	.471	.524	.671	.825	1.012
3	2.17	8.16	60.0	.505	.509	.557	.621	.755	.908
4	2.17	8.07	60.0	.536	.542	.623	.691	.752	.945
5	2.21	8.11	52.5	.490	.507	.558	.646	.750	1.004
6	2.21	8.05	45.0	.476	.485	.555	.711	.871	1.165
7	2.21	8.06	37.5	.511	.531	.622	.788	.926	1.079
8	2.21	8.30	30.0	.581	.607	.638	.760	.880	1.140
9	1.68	8.46	22.5	.726	.751	.839	.961	1.075	1.360
10	2.31	7.94	15.0	.791	.818	.871	1.078	1.113	1.171
11	2.37	5.46	7.5	.704	.706	.743	.834	1.042	1.148

R011241488 245 5

2	1.47	9.17	60.0	.513	.528	.582	.628	.712	.782
3	1.46	9.04	60.0	.514	.525	.539	.611	.678	.753
4	1.47	8.90	60.0	.539	.562	.578	.637	.767	.860
5	1.47	8.85	52.5	.529	.545	.558	.623	.724	.761
6	1.47	8.75	45.0	.527	.545	.588	.648	.737	.817
7	1.47	8.72	37.5	.545	.560	.610	.689	.748	.786
8	1.47	8.82	30.0	.569	.587	.612	.684	.791	.934
9	1.47	9.04	22.5	.652	.669	.714	.820	.915	.987
10	1.47	8.52	15.0	.743	.770	.820	.897	.945	.984
11	1.52	5.30	7.5	.700	.717	.765	.893	.924	1.074

R011241457 245 5												
2	1.46	9.18	60.0	.518	.520	.579	.624	.721	.737			
3	1.46	9.06	60.0	.523	.529	.546	.625	.679	.722			
4	1.46	8.92	60.0	.551	.562	.584	.635	.748	.833			
5	1.46	8.86	52.5	.542	.546	.559	.638	.727	.781			
6	1.46	8.72	45.0	.525	.558	.600	.657	.744	.801			
7	1.47	8.69	37.5	.554	.570	.608	.690	.742	.803			
8	1.47	8.81	30.0	.571	.583	.614	.687	.785	.925			
9	1.47	9.04	22.5	.638	.671	.714	.805	.925	.985			
10	1.47	8.51	15.0	.754	.764	.794	.887	.957	.971			
11	1.54	5.32	7.5	.694	.699	.787	.872	.975	1.035	1.062		
R0112415 7 345 5												
2	1.47	9.54	60.0	.533	.552	.573	.689	.740	.857			
3	1.47	9.34	60.0	.535	.544	.590	.701	.837	.900			
4	1.47	9.28	60.0	.523	.542	.594	.644	.829	.942			
5	1.47	9.27	52.5	.517	.532	.579	.685	.816	.969			
6	1.47	9.15	45.0	.545	.566	.587	.731	.801	.938			
7	1.47	9.02	37.5	.550	.588	.657	.721	.854	1.109			
8	1.47	9.09	30.0	.568	.576	.660	.719	.863	1.245			
9	1.47	9.17	22.5	.700	.719	.760	.916	1.003	1.074			
10	1.47	8.46	15.0	.808	.832	.867	.965	1.016	1.026			
11	1.47	5.47	7.5	.707	.733	.809	.902	1.012	1.078			
R011241439 145 5												
2	2.17	8.20	60.0	.464	.471	.524	.671	.825	1.012			
3	2.17	8.16	60.0	.505	.504	.557	.621	.755	.908			
4	2.17	8.07	60.0	.516	.542	.623	.691	.782	.945			
5	2.21	8.11	52.5	.490	.507	.558	.646	.750	1.004			
6	2.21	8.05	45.0	.476	.485	.555	.711	.871	1.165			
7	2.21	8.06	37.5	.511	.531	.622	.788	.926	1.079			
8	2.21	8.30	30.0	.581	.607	.638	.760	.880	1.140			
9	1.68	8.46	22.5	.726	.751	.839	.961	1.075	1.360			
10	2.31	7.94	15.0	.741	.818	.871	1.078	1.113	1.171			
11	2.37	5.46	7.5	.704	.766	.743	.834	1.042	1.148			
R011241448 245 5												
2	1.47	9.17	60.0	.513	.524	.582	.628	.712	.762			
3	1.46	9.04	60.0	.514	.525	.539	.611	.678	.753			
4	1.47	8.90	60.0	.534	.546	.578	.637	.767	.860	.891		
5	1.47	8.85	52.5	.524	.545	.558	.623	.724	.761			
6	1.47	8.75	45.0	.527	.545	.588	.688	.737	.817			
7	1.47	8.72	37.5	.545	.560	.610	.689	.798	.786			
8	1.47	8.82	30.0	.584	.597	.612	.694	.791	.934			
9	1.47	9.04	22.5	.652	.669	.714	.820	.915	.987			
10	1.47	8.52	15.0	.743	.770	.820	.897	.945	.984			
11	1.52	5.30	7.5	.700	.717	.765	.893	.924	1.074			
R011241457 245 5												
2	1.46	9.18	60.0	.518	.520	.579	.624	.721	.737			
3	1.46	9.06	60.0	.523	.529	.546	.625	.679	.722			
4	1.46	8.92	60.0	.551	.562	.584	.635	.748	.833			
5	1.46	8.86	52.5	.542	.546	.559	.638	.727	.781			
6	1.46	8.72	45.0	.525	.558	.600	.657	.744	.801			
7	1.47	8.69	37.5	.554	.570	.608	.690	.742	.803			
8	1.47	8.81	30.0	.571	.583	.614	.687	.785	.925			
9	1.47	9.04	22.5	.638	.671	.714	.805	.925	.985			
10	1.47	8.51	15.0	.754	.764	.794	.887	.957	.971			
11	1.54	5.32	7.5	.694	.699	.787	.872	.975	1.035	1.062		
R0112415 7 345 5												
2	1.47	9.54	60.0	.533	.552	.573	.689	.740	.857			
3	1.47	9.34	60.0	.535	.544	.590	.701	.837	.900			
4	1.47	9.28	60.0	.523	.542	.594	.644	.829	.942			
5	1.47	9.27	52.5	.517	.532	.579	.685	.816	.969			
6	1.47	9.15	45.0	.545	.566	.587	.731	.801	.938			
7	1.47	9.02	37.5	.550	.588	.657	.721	.854	1.109			
8	1.47	9.09	30.0	.568	.576	.660	.719	.863	1.245			
9	1.47	9.17	22.5	.700	.719	.760	.916	1.003	1.074			
10	1.47	8.46	15.0	.808	.832	.867	.965	1.016	1.026			
11	1.47	5.47	7.5	.707	.733	.809	.902	1.012	1.078			
R011241321 675 10												
2	1.84	10.11	60.0	.529	.539	.573	.641	.768	.869			
3	1.74	10.04	60.0	.537	.546	.603	.748	.919	.996			
4	1.84	9.96	60.0	.505	.512	.574	.685	.757	.778			
5	1.84	9.43	52.5	.536	.548	.584	.625	.917	.960			
6	1.84	9.90	45.0	.544	.576	.589	.656	.796	.939			
7	1.84	9.80	37.5	.572	.579	.606	.750	.868	1.098			
8	1.86	9.83	30.0	.587	.605	.666	.785	.967	1.135			
9	1.84	9.83	22.5	.685	.712	.760	.876	1.052	1.109			
10	1.86	8.77	15.0	.759	.767	.817	.876	.998	1.068			
11	2.10	5.57	7.5	.691	.722	.781	.862	.973	1.106			

#011241332 775 10

2	4.20	10.90	60.0	.567	.575	.635	.771	1.008	1.051
3	4.20	10.64	60.0	.583	.597	.627	.761	1.044	1.160
4	4.20	10.66	60.0	.631	.638	.728	.775	1.105	1.202
5	4.20	10.73	52.5	.612	.638	.691	.736	1.043	1.290
6	4.20	10.89	45.0	.672	.677	.713	.818	.999	1.457
7	4.20	11.04	37.5	.692	.713	.766	.833	1.069	1.723
8	4.20	11.34	30.0	.784	.820	.879	.940	1.280	1.650
9	4.20	11.62	22.5	.923	.937	.949	1.088	1.280	1.334
10	4.20	10.31	15.0	.888	.915	.949	1.043	1.177	1.287
11	4.41	7.04	7.5	.642	.668	.725	.792	.895	.916

#011241341 775 10

2	4.20	10.85	60.0	.574	.603	.647	.692	1.022	1.067
3	4.20	10.73	60.0	.566	.573	.624	.758	1.049	1.168
4	4.20	10.73	60.0	.608	.641	.720	.766	1.114	1.231
5	4.27	10.85	52.5	.603	.623	.676	.729	1.028	1.263
6	4.27	10.88	45.0	.680	.684	.703	.813	1.014	1.477
7	4.27	11.06	37.5	.698	.715	.754	.827	1.044	1.688
8	4.27	11.32	30.0	.769	.791	.873	.972	1.197	1.666
9	4.20	11.63	22.5	.941	.946	.993	1.127	1.515	1.362
10	4.20	10.36	15.0	.886	.923	.974	1.059	1.189	1.264
11	4.66	7.14	7.5	.675	.696	.735	.793	.985	1.026

#011241431 145 5

2	2.17	8.12	60.0	.477	.481	.525	.682	.838	1.030
3	2.17	8.04	60.0	.500	.511	.565	.624	.767	.908
4	2.17	7.95	60.0	.541	.553	.618	.705	.781	.958
5	2.17	7.99	52.5	.495	.505	.566	.648	.746	1.014
6	2.17	8.04	45.0	.483	.493	.550	.719	.697	1.158
7	2.17	8.01	37.5	.508	.527	.591	.785	.940	1.061
8	2.17	8.21	30.0	.550	.586	.634	.773	.909	1.101
9	1.68	8.44	22.5	.720	.728	.820	.971	1.084	1.327
10	2.31	7.97	15.0	.782	.800	.856	1.016	1.111	1.138
11	2.37	5.46	7.5	.737	.746	.778	.842	1.001	1.163

#01124156 475 10

2	2.72	8.11	60.0	.571	.577	.609	.776	.835	.852
3	2.72	8.13	60.0	.556	.573	.604	.740	.770	.811
4	2.72	8.07	60.0	.540	.575	.618	.741	.809	.892
5	2.72	8.22	52.5	.552	.576	.634	.723	.815	.979
6	2.70	8.42	45.0	.586	.593	.634	.797	.890	1.145
7	2.70	8.59	37.5	.685	.681	.712	.942	1.083	1.278
8	2.70	8.85	30.0	.740	.763	.875	1.135	1.235	1.488
9	2.67	9.10	22.5	.935	.964	1.158	1.326	1.492	1.505
10	3.51	8.06	15.0	.948	.986	1.027	1.171	1.231	1.256
11	9.14	5.71	7.5	.751	.763	.796	.852	1.176	1.305

#011241244 575 10

2	2.61	5.36	60.0	.509	.516	.574	.733	.941	
3	2.61	5.35	60.0	.470	.488	.539	.712	.874	.950
4	2.61	5.30	60.0	.491	.503	.576	.729	.916	.971
5	2.61	5.37	52.5	.492	.503	.578	.725	.925	.994
6	2.61	5.45	45.0	.524	.554	.661	.763	.937	1.164
7	2.61	5.57	37.5	.565	.591	.730	.925	1.020	1.318
8	2.61	5.75	30.0	.593	.622	.777	.950	1.313	1.537
9	2.61	6.06	22.5	.661	.708	.825	1.104	1.436	1.826
10	2.59	5.91	15.0	.692	.956	1.028	1.452	1.570	1.712
11	3.51	4.53	7.5	.790	.619	.914	1.021	1.192	1.248

#011241259 575 10

2	2.61	5.36	60.0	.503	.509	.577	.723	.945	1.067
3	2.61	5.36	60.0	.476	.492	.537	.713	.884	.961
4	2.61	5.32	60.0	.492	.500	.584	.722	.904	.968
5	2.61	5.39	52.5	.493	.517	.573	.732	.934	1.010
6	2.61	5.47	45.0	.530	.558	.671	.786	.939	1.167
7	2.61	5.58	37.5	.560	.572	.717	.909	1.017	1.323
8	2.61	5.78	30.0	.596	.617	.768	.954	1.341	1.554
9	2.61	6.09	22.5	.712	.749	.946	1.232	1.639	1.858
10	2.59	5.91	15.0	.696	.975	1.040	1.442	1.572	1.765
11	3.51	4.56	7.5	.743	.671	.965	1.094	1.165	1.173

#011241310 675 10

2	1.84	10.17	60.0	.522	.536	.585	.667	.783	.840
3	1.74	10.05	60.0	.521	.540	.604	.751	.900	1.002
4	1.84	9.98	60.0	.510	.519	.569	.675	.744	.780
5	1.84	9.92	52.5	.533	.545	.562	.612	.629	.955
6	1.84	9.89	45.0	.541	.566	.598	.668	.861	.937
7	1.84	9.75	37.5	.576	.586	.624	.771	.869	1.136
8	1.86	9.83	30.0	.594	.613	.665	.801	.968	1.141
9	1.84	9.81	22.5	.686	.704	.754	.876	1.061	1.114
10	2.06	8.75	15.0	.790	.804	.835	.887	.969	1.060
11	2.10	5.55	7.5	.662	.720	.784	.833	1.030	1.071 1.208

R0112411 2 275 10

2	1.47	13.84	60.0	.537	.540	.582	.673	.752	.838
3	1.46	13.65	60.0	.559	.563	.618	.667	.759	.828
4	1.46	13.47	60.0	.558	.565	.593	.688	.799	.833
5	1.46	13.48	52.5	.575	.608	.626	.673	.839	.916
6	1.46	13.32	45.0	.603	.609	.642	.715	.869	.906
7	1.47	13.11	37.5	.595	.602	.624	.752	.856	.920
8	1.47	13.01	30.0	.655	.680	.737	.786	.835	.895
9	1.47	12.30	22.5	.709	.717	.742	.793	.838	.873
10	1.47	4.65	15.0	.723	.727	.757	.813	.943	1.052
11	8.53	5.68	7.5	.682	.684	.745	.889	.954	1.028

R011241111 275 10

2	1.46	13.86	60.0	.530	.537	.587	.679	.752	.878
3	1.46	13.69	60.0	.558	.569	.612	.684	.756	.803
4	1.46	13.60	60.0	.560	.571	.593	.691	.806	.852
5	1.46	13.52	52.5	.573	.593	.618	.672	.851	.908
6	1.46	13.33	45.0	.586	.597	.651	.709	.895	.941
7	1.47	13.16	37.5	.586	.594	.639	.734	.844	.884
8	1.47	13.06	30.0	.678	.686	.723	.795	.854	.880
9	1.47	12.30	22.5	.697	.708	.753	.832	.874	.889
10	1.47	4.76	15.0	.726	.743	.770	.829	.936	1.016
11	8.53	5.70	7.5	.639	.653	.712	.877	.957	1.059

R011241121 375 10

2	1.67	13.87	60.0	.565	.605	.636	.722	.833	.929
3	1.67	13.76	60.0	.533	.542	.577	.687	.800	1.056
4	1.67	13.65	60.0	.562	.564	.589	.686	.769	1.116
5	1.67	13.66	52.5	.556	.542	.596	.738	.871	1.091
6	1.67	13.48	45.0	.612	.627	.670	.741	.837	.981
7	1.67	13.16	37.5	.629	.651	.716	.820	.940	.954
8	1.67	12.49	30.0	.690	.722	.750	.856	.920	.955
9	1.67	12.43	22.5	.706	.717	.764	.856	.954	1.002
10	1.67	4.66	15.0	.704	.712	.769	.871	.954	1.032
11	8.26	6.03	7.5	.629	.652	.713	.797	.914	1.088

R011241130 375 10

2	1.67	14.05	60.0	.578	.602	.621	.717	.803	.918
3	1.67	13.96	60.0	.532	.540	.577	.680	.804	.984
4	1.67	13.79	60.0	.546	.555	.591	.677	.769	1.059
5	1.67	13.70	52.5	.532	.537	.580	.700	.841	1.097
6	1.67	13.30	45.0	.600	.626	.670	.751	.833	.950
7	1.67	13.09	37.5	.641	.651	.708	.805	.925	1.014
8	1.67	12.47	30.0	.686	.703	.790	.868	.926	.943
9	1.67	12.39	22.5	.738	.752	.787	.868	.912	.985
10	1.67	4.71	15.0	.694	.704	.766	.852	.908	.975
11	8.26	6.05	7.5	.622	.637	.681	.800	.924	1.140

R011211416 760 10

2	3.56	12.17	59.9	.587	.618	.736	.912	1.151	1.205
3	3.56	11.94	59.9	.634	.642	.673	.899	1.096	1.158
4	3.56	11.84	59.9	.591	.605	.731	.847	1.115	1.132
5	3.56	12.02	52.4	.632	.657	.735	.818	1.064	1.090
6	3.56	12.11	44.9	.619	.665	.760	.862	1.061	1.226
7	3.56	12.39	37.4	.677	.700	.747	.933	1.148	1.221
8	3.56	12.67	29.9	.740	.766	.857	.968	1.165	1.418
9	4.66	12.81	22.4	.860	.894	.992	1.072	1.217	1.340
10	4.66	10.65	14.9	.820	.851	.891	1.026	1.121	1.262
11	4.49	7.44	7.4	.576	.591	.704	.791	.886	.948

R011211425 860 10

2	3.61	12.18	59.9	.600	.629	.739	.930	1.175	1.269
3	3.61	12.09	59.9	.632	.643	.699	.902	1.100	1.150
4	3.61	11.90	59.9	.601	.650	.716	.844	1.097	1.114
5	3.61	12.16	52.4	.659	.672	.732	.829	1.057	1.084
6	3.61	12.20	44.9	.661	.716	.776	.857	1.039	1.203
7	3.61	12.57	37.4	.675	.687	.764	.934	1.131	1.170
8	3.61	12.86	29.9	.760	.803	.848	.976	1.140	
9	3.61	12.98	22.4	.841	.909	.955	1.091	1.165	1.256
10	4.66	10.79	14.9	.850	.869	.940	1.030	1.122	1.274
11	4.49	7.64	7.4	.587	.597	.683	.791	.906	1.012

R011211445 86010

2	3.41	14.54	59.9	.617	.653	.733	.814	.964	1.194
3	3.41	14.28	59.9	.581	.607	.685	.793	.944	1.105
4	3.41	14.22	59.9	.637	.655	.690	.869	1.015	1.260
5	3.41	14.28	52.4	.565	.597	.679	.836	.957	1.353
6	3.41	14.26	44.9	.661	.702	.755	.864	1.076	1.434
7	3.41	14.48	37.4	.665	.676	.721	.857	1.102	1.269
8	3.51	14.45	29.9	.749	.754	.878	1.089	1.183	1.400
9	4.83	13.98	22.4	.622	.844	.887	.970	1.079	1.217
10	4.92	11.40	14.9	.762	.780	.854	.993	1.018	1.107
11	5.02	7.73	7.4	.606	.621	.689	.808	.937	1.052

A011211456 260 4

2	1.52	7.6A	54.4	.471	.4A7	.521	.611	.603	1.096	1.601
3	1.52	7.50	54.4	.534	.544	.5A2	.630	.67A	1.258	1.306
4	1.54	7.40	54.4	.504	.513	.5A0	.643	.631	1.379	1.478
5	1.54	7.3A	52.4	.476	.490	.538	.6A3	.916	1.1A5	1.257
6	1.54	7.27	44.4	.511	.516	.546	.633	.624	1.007	1.530
7	1.54	7.17	37.4	.522	.533	.570	.634	.951	1.366	1.406
8	1.54	7.40	24.4	.518	.532	.595	.701	1.014	1.403	1.535
9	1.54	7.10	22.4	.575	.5A1	.626	.626	.952	1.539	
10	1.56	6.79	14.4	.692	.730	.803	.9A3	1.104	1.152	
11	1.56	5.13	7.4	.710	.724	.754	.874	.953	1.051	1.115

A0112115 5 260 4

2	1.50	8.71	59.4	.452	.465	.541	.665	1.01A	1.254	1.448
3	1.50	8.49	59.4	.496	.502	.526	.725	1.153	1.186	1.610
4	1.50	8.46	59.4	.4A6	.514	.537	.691	.951	1.275	1.323
5	1.50	8.44	52.4	.497	.506	.543	.700	.915	1.146	1.406
6	1.50	8.34	44.4	.494	.512	.535	.639	.886	1.213	
7	1.50	8.16	37.4	.500	.512	.526	.700	1.039	1.234	
8	1.50	8.36	29.4	.528	.542	.572	.717	1.1A5	1.241	
9	1.52	7.85	22.4	.575	.608	.664	.797	.993	1.336	
10	1.52	7.37	14.4	.733	.767	.818	.920	.994	1.057	
11	1.52	5.26	7.4	.712	.740	.811	.907	.9A9	1.047	1.119

A011211514 360 4

2	1.67	8.00	59.4	.461	.4A3	.532	.635	1.044	1.298	
3	1.67	7.86	59.4	.472	.4A3	.500	.5A2	.834	1.215	
4	1.67	7.77	59.4	.494	.511	.541	.601	.829	1.219	
5	1.67	7.7A	52.4	.477	.502	.561	.656	.845	1.228	
6	1.67	7.69	44.4	.494	.501	.545	.654	.827	1.263	
7	1.67	7.66	37.4	.522	.542	.575	.657	1.107	1.229	
8	1.67	7.9A	29.4	.546	.567	.625	.741	1.234	1.536	
9	1.67	7.57	22.4	.641	.649	.721	.821	1.056	1.308	
10	1.71	7.24	14.4	.799	.818	.876	.96A	1.098	1.128	
11	1.73	5.16	7.4	.700	.707	.776	.896	1.018	1.151	

A011211523 360 4

2	1.66	8.30	59.4	.476	.494	.538	.635	1.007	1.253	
3	1.66	8.10	54.4	.476	.4A0	.511	.576	.821	1.169	
4	1.66	7.99	54.4	.516	.51A	.544	.605	.605	1.204	
5	1.66	7.9A	52.4	.495	.527	.577	.6A6	.854	1.228	
6	1.66	7.92	44.4	.4A4	.493	.578	.674	.946	1.250	
7	1.66	7.91	37.4	.542	.557	.596	.644	1.079	1.192	
8	1.66	8.23	29.4	.56A	.592	.664	.754	1.177	1.505	
9	1.66	7.87	22.4	.644	.6A8	.738	.805	1.065	1.255	
10	1.67	7.47	14.4	.812	.A32	.6A7	.9A5	1.104	1.143	
11	1.67	5.20	7.4	.724	.732	.770	.8A3	.9A3	1.114	

APPENDIX E

CNOIDAL WAVE TESTS RESULTS

Wave height (cm)	Wave period (s)	Water depth (cm)	Relative crest height η/H
11.278	2.30	44.05	0.6260
11.583	2.80	44.05	0.6658
11.433	3.40	44.05	0.7526
11.468	4.10	44.05	0.7678
11.590	4.80	44.05	0.7767
11.464	5.70	44.05	0.8118
21.58	1.60	44.05	0.6330
21.67	2.00	44.05	0.6470
23.38	2.40	44.05	0.6895
23.52	2.40	44.05	0.7258
21.88	2.90	44.05	0.7724
23.104	3.39	44.05	0.7228
22.25	4.00	44.05	0.8036

APPENDIX F

ESTIMATING THE WAVE CREST ELEVATION AT BREAKING ON A PLANE SLOPE

The equations of Singamsetti and Wind (1980) can be used with the methods developed in this report to predict the crest elevation at the breaking point for monochromatic waves normally incident to a slope. This technique uses as input water depth, d , wave height, H , and period, T , in a constant depth region offshore of a plane slope, m . Deepwater wave height is found from

$$H'_O = \frac{H}{\sqrt{\frac{1.0}{\tanh\left(\frac{2\pi d}{L_A}\right) \left[1.0 + \frac{4\pi d/L_A}{\sinh(4\pi d/L_A)}\right]}}} \quad (F-1)$$

where L_A is the wavelength from Airy theory

$$L_A = \frac{gT^2}{2\pi} \tanh\left(\frac{2\pi d}{L_A}\right) \quad (F-2)$$

Breaking wave height may be determined from

$$H_b = H'_O 0.575(m)^{0.031} (H'_O/L_O)^{-0.254} \quad (F-3)$$

where L_O is deepwater Airy wavelength

$$L_O = \frac{gT^2}{2\pi} \quad (F-4)$$

Depth at breaking, d_b , is found from

$$d_b = H_b (1.067)(m)^{-0.155} (H'_O/L_O)^{0.130} \quad (F-5)$$

$$\text{for } \frac{1}{40} < m < \frac{1}{5}$$

$$d_b = H_b (1.761)(m)^{-0.107} (H'_O/L_O)^{0.237}$$

$$\text{for } m = \frac{1}{5}$$

The value of d_b/L_O is used to determine A_2 and A_3 from Figure 6 in the test of this report; A_1 is determined from the value of the beach slope using Figure 7. Crest height at breaking, $(\eta_c)_b$, is then given by

$$(\eta_c)_b = \frac{A_1 H_b}{1.0 + \tanh \left[-A_2 \ln \left(A_3 \frac{H_b}{L_O} \right) \right]} \quad (F-6)$$

Seelig, William N. The elevation and duration of wave crests / by William N. Seelig, John P. Ahrens, and William G. Grosskopf--Fort Belvoir, Va. : U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Springfield, Va. : available from NTIS, 1983. [73] p. : ill. : 28 cm.--(Miscellaneous report / Coastal Engineering Research Center ; no. 83-1) Cover title. "January 1983." Report provides techniques for estimating crest elevation and duration for both nonbreaking and breaking wave conditions. Dean's (1974) stream-function wave theory and monochromatic and irregular laboratory wave data are used. 1. Irregular waves. 2. Monochromatic waves. 3. Wave breaking. 4. Wave crests. I. Title. II. Ahrens, John P. III. Grosskopf, William G. IV. Coastal Engineering Research Center (U.S.). V. Series: Miscellaneous report (Coastal Engineering Research Center (U.S.)); no. 83-1. TC203 no. 83-1 .U58lmr 627	Seelig, William N. The elevation and duration of wave crests / by William N. Seelig, John P. Ahrens, and William G. Grosskopf--Fort Belvoir, Va. : U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Springfield, Va. : available from NTIS, 1983. [73] p. : ill. : 28 cm.--(Miscellaneous report / Coastal Engineering Research Center ; no. 83-1) Cover title. "January 1983." Report provides techniques for estimating crest elevation and duration for both nonbreaking and breaking wave conditions. Dean's (1974) stream-function wave theory and monochromatic and irregular laboratory wave data are used. 1. Irregular waves. 2. Monochromatic waves. 3. Wave breaking. 4. Wave crests. I. Title. II. Ahrens, John P. III. Grosskopf, William G. IV. Coastal Engineering Research Center (U.S.). V. Series: Miscellaneous report (Coastal Engineering Research Center (U.S.)); no. 83-1. TC203 no. 83-1 .U58lmr 627
Seelig, William N. The elevation and duration of wave crests / by William N. Seelig, John P. Ahrens, and William G. Grosskopf--Fort Belvoir, Va. : U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Springfield, Va. : available from NTIS, 1983. [73] p. : ill. : 28 cm.--(Miscellaneous report / Coastal Engineering Research Center ; no. 83-1) Cover title. "January 1983." Report provides techniques for estimating crest elevation and duration for both nonbreaking and breaking wave conditions. Dean's (1974) stream-function wave theory and monochromatic and irregular laboratory wave data are used. 1. Irregular waves. 2. Monochromatic waves. 3. Wave breaking. 4. Wave crests. I. Title. II. Ahrens, John P. III. Grosskopf, William G. IV. Coastal Engineering Research Center (U.S.). V. Series: Miscellaneous report (Coastal Engineering Research Center (U.S.)); no. 83-1. TC203 no. 83-1 .U58lmr 627	Seelig, William N. The elevation and duration of wave crests / by William N. Seelig, John P. Ahrens, and William G. Grosskopf--Fort Belvoir, Va. : U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Springfield, Va. : available from NTIS, 1983. [73] p. : ill. : 28 cm.--(Miscellaneous report / Coastal Engineering Research Center ; no. 83-1) Cover title. "January 1983." Report provides techniques for estimating crest elevation and duration for both nonbreaking and breaking wave conditions. Dean's (1974) stream-function wave theory and monochromatic and irregular laboratory wave data are used. 1. Irregular waves. 2. Monochromatic waves. 3. Wave breaking. 4. Wave crests. I. Title. II. Ahrens, John P. III. Grosskopf, William G. IV. Coastal Engineering Research Center (U.S.). V. Series: Miscellaneous report (Coastal Engineering Research Center (U.S.)); no. 83-1. TC203 no. 83-1 .U58lmr 627

